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EVALUATION OF NUCLEAR RESEARCH CORPORATION'S ADM-300 RADIATION DETECTION, INDICATION, AND COMPUTATION (RADIAC) INSTRUMENT

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ARMSTRONG LABORATORY

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An evaluation of Nuclear Research Corporation's ADM-300 RADIAC survey meter was requested by HQ USAF/XOOTM as a possible replacement for the AN/PDR-27 and AN/PDR-43 survey meters. This evaluation was performed in accordance with criteria specified in ANSI N42.17A-1989 and MIL-STD-810D (1983). Two configurations of the ADM-300 were tested: (1) ADM-300 with beta/gamma detectors along the side, and (2) ADM-300 with beta/gamma detectors along the bottom. The ADM-300 passed most ANSI N42.17A criteria. It has a flat energy response from 252 keV to 1,250 keV, deviates from the true delivered exposure by less than 5% from 1 µR/hr to 2,000 R/hr, and passes all environmental test conditions when the ANSI N42.17A general criteria of ±15% is applied. The angular dependence of the ADM-300 with the beta/gamma detectors along the bottom is less severe than the ADM-300 with the beta/gamma detectors along the side. External probes are available for the ADM-300, and these should be subjected to similar testing prior to procurement.

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INTRODUCTION

Purpose

The Air Force RADIAC Working Group (AFRWG) convened in Mar 91 and recognized the need for a quality instrument that could serve the needs of the Air Force until the Defense Nuclear Agency's Multifunction RADIAC instrument could be developed and procured. AFRWG looked for an off-the-shelf instrument that could replace the AN/PDR-27 and the AN/PDR-43 and provide an additional expansion capability if desired by the user. The only off-the-shelf instrument available at that time that looked capable of meeting these diverse requirements was Nuclear Research Corporation's (NRC) ADM-300. The AFRWG decided testing of the NRC ADM-300 should be performed to determine whether it is a suitable replacement for these instruments. HQ USAF/CEOR (formerly HQ USAF/XOOTM) tasked Armstrong Laboratory with performing this testing.

Armstrong Laboratory's Radiation Dosimetry Function (AL/OEBSD) evaluated NRC's ADM-300 RADIAC instrument during Jul-Sep 91. This report outlines the results of radiation and environmental testing in accordance with a selected protocol to simulate field environmental conditions and various uses of the instrument. The report also outlines the response of the ADM-300 to nationally established standards for portable RADIAC instruments.

METHODS, ASSUMPTIONS, AND PROCEDURES

Protocols and Standards for Testing

Since there is no military radiation testing protocol for RADIAC instruments, Armstrong Laboratory's Instrumentation and Calibration Facility selected radiation performance protocol and criteria from the American National Standard Institute (ANSI) Standard N42.17A-1989, Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Environmental Conditions (1) (hereafter referred to as ANSI N42.17A), and tested the ADM-300 against these selected criteria.

To ensure adequate testing of the instrument under simulated field conditions, selected protocols from MIL-STD-810D, Environmental Test Methods and Engineering Guidelines (2) (hereafter referred to as MIL-STD-810D), and augmented, where necessary, with protocols from ANSI N42.17A. Since MIL-STD-810D does not provide criteria or acceptance limits for instrument evaluations, the general ANSI N42.17A criteria, a ± 15% change in the instrument response for the particular test being conducted, was applied to all environmental test results.

To determine whether the ADM-300 is a suitable substitute for the AN/PDR-27 and AN/PDR-43, the test results were evaluated against the reference data (Table 1) for these two RADIAC instruments as found in Technical Order (T.O.) 11H4-7-3-201, RADIAC Set AN/PDR-27T - Operation, Maintenance and Overhaul with Parts Breakdown (3) (hereafter referred to as T.O. 11H4-7-3-201), and T.O. 11H4-7-3-181, RADIAC set AN/PDR-43E (4) (hereafter referred to as T.O. 11H4-7-3-181).

Both test protocols were coordinated with HQ HSD/YAMC, the USAF RADIAC Instrumentation Program Office, and informational copies were provided to Mr Bill Allen, SA-ALC/LDIL, the USAF Item Manager for RADIAC instrumentation. These protocols are provided in Appendix A and Appendix B.

TABLE 1. REFERENCE DATA FOR THE AN/PDR-27 AND AN/PDR-43

Item	T.O. 11H4-7-3-201 AN/PDR-27T (3)	T.O. 11H4-7-3-181 AN/PDR-43E (4)
Operating Temperature	-40 °C - +60 °C	-40 °C - +50 °C
Range	0 - 500 mR/hr	0 - 500 R/hr
Scales	Four	Three
Operating Altitude	Any altitude up to 50,000 feet	
Power	Battery power for up to 50 hours of continuous operation	
Accuracy	± 20% from 10% full scale on each range throughout entire operating temperature range	
Energy Range	Measures gamma from 80 keV to 2 MeV[a] Detects beta radiation	
Battery Check	Meter indication of battery condition	

[a]The energy response of the RADIAC (flat within ±20% 80 keV to 2 MeV) is such that a dip in response occurs at 662 keV, the characteristic radiation from Cs-137 (3, 4).

Testing Equipment and Radiation Sources

Environmental Testing

AL/OEBSD coordinated the environmental testing with the Technical Services Division of Armstrong Laboratory's Operations and Support Directorate (AL/DOJE), performed general health physics testing, and evaluated all test data. AL/DOJE provided the environmental testing chamber (Standard Environmental Systems, Model # TAH/15, Serial # 80066) and their support for this effort.

Radiation Testing

Radiation testing was conducted in AL/OEBSD's Instrumentation and Calibration Facility (ICF) with various radiation sources being used in this effort. They include a 130 millicurie (mCi) and a 130 Curie (Ci) Cesium 137 (Cs-137) source used in the ICF's J. L. Shepherd and Associates irradiator (Model 6810), a 9340 Ci Cobalt-60 (Co-60) source (serial number S-3999) used in the Atomic Energy of Canada Limited Teletherapy Unit (Model E-78) belonging to Armstrong Laboratory's Directed Energy Division (AL/OED), and various check sources as listed in Table 2. All sources are traceable to the National Institute of Science and Technology (NIST). To confirm the exposure to the ADM-300, an EXRADIN Ion Chamber (Model A2, Serial # 159) was used in all instances where an irradiator was used.

Instrument Specifications

Manufacturer's Information

The Operator's Manual, ADM-300 Multifunction Survey Meter (3), states that the ADM-300 is a portable compact, microprocessor-based survey meter with two built-in wide range gamma radiation detectors. It weighs less than 3 pounds (1,200 grams), can be carried in a special pouch with a belt clip and strap for hands-free operation, and has the maximum dimensions of 20 cm X 11 cm X 6 cm. The ADM-300 basic unit is a Geiger-Mueller (GM) instrument capable of being used in radiation fields varying between 60 keV to 3 MeV. The readings are displayed on the unit by a two-line, 16-character dot matrix liquid crystal display (LCD) at one end of the unit. At the cpposite end of the instrument is a water-tight, quick-disconnect serial RS-232 communications output port and an interface port to connect external smart probes to the instrument package, making it capable of multifunctional monitoring for all forms of radiation. The unit is powered by six AA batteries or can be adapted for several types of battery configurations and provides at least 100 hours of continuous operations under normal field conditions.

TABLE 2. CHECK SOURCES USED FOR RADIATION TESTING

Source Set	Nuclide	Source No.	Nominal Activity (μCi)	Decayed Activity (μCi)[a]
Amersham #2087	Am-241	2Q154	11.97	11.89
	Ba-133	2R057	10.52	6.97
	Cs-137	2S376	11.28	10.17
	Co-60	2U338	12.14	6.75
	Na-22	2X16[illegible]	11.39	3.49
Amersham #2089	Am-241	2Q156	12.45	12.37
	Ba-133	2R059	10.18	6.74
	Cs-137	2S380	11.50	10.37
	Co-60	2U340	11.95	6.64
	Na-22	2X169	11.22	3.44

Beta Nuclide	Source No.	Decayed Activity (nCi)[b]
C-14	815	103.4
Tc-99	816	9.66
Cl-36	817	9.24
Pb-210	818	10.93
Pm-147	819	4.27
Sr-90	820	9.41

Alpha Nuclide	Source No.	Decayed Activity (DPM)[c]
Pu-239	845	6415.3

[a]Microcuries as of 17 Sep 91
[b]Nanocuries as of 1 Oct 91
[c]Disintegration per minute as of 1 Oct 91

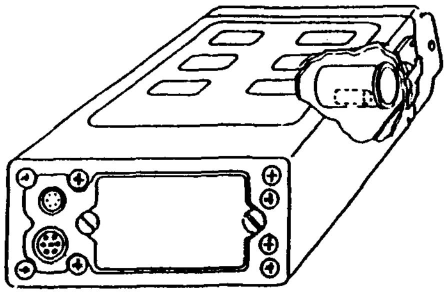
The ADM-300 microprocessor executes a self-diagnostic routine and reports any failures when the instrument is first turned on. Any detector failure is displayed automatically. The unit provides an automatic low battery indication and can still operate under normal conditions for approximately 5 hours after the indicator has been illuminated. The ADM-300 provides audible and visual alarms for the exposure rate and the accumulated dose if set by the user. The memory circuitry is nonvolatile for massive storage of data. The unit can be connected to a computer for full diagnostic troubleshooting or downloading of the collected data.

The basic electronics unit contains two halogen quenched GM tubes to cover the range of 10 microroentgen/hour (μR/hr) to 10,000 roentgen/hour (R/hr). One GM tube operates from 10 μR/hr to 5 R/hr, and the other one operates from 5 R/hr to 10,000 R/hr. The accumulated dose is measured throughout the range of 0-10,000 rads. The built-in low range GM tube has a 3-4 mg/cm^2 beta sensitive end window for beta monitoring in the range of 10 μR/hr - 5 R/hr for beta energies greater than 200 keV. The ADM-300 uses a "TIME-TO-COUNT" principle in operating the GM tubes allowing the instrument to auto range over the 9 decades of radiation intensity without the problems of such things as nonlinearity, coincidence loss, and tube saturation as found in conventional systems.

According to the advertised specifications (9), the ADM-300 is linear throughout its range to within ± 5% of the true dose rate, has an accuracy of ± 15%, and two or more ADM-300s will have their readings within ± 15% when placed in the same exposure environment. The instrument is designed to operate from a -35 °C to 60 °C at any altitude up to 50,000 feet.

<u>Items Tested</u>

Armstrong Laboratory's Radiation Consultation Function (AL/OEBSC), which had received three NRC ADM-300 instruments as an upgrade to their neutron measurement capability, offered to use their instruments for the radiation testing portion of this test. These instruments have the beta/gamma detectors mounted along the side of the unit (Fig. 1). However, since these instruments were intended for field support, and environmental testing can damage instruments, another NRC ADM-300 was obtained from the manufacturer. This instrument has a pistol-type grip with the beta/gamma detectors along the bottom of the instrument instead of along the side as with the AL/OEBSC instruments (Fig. 2). The pistol grip unit is designed so that the beta window will be pointed towards the source being measured. The differences between these two styles were considered to have minimal impact on most test results. In those instances where an effect could be possible, the pistol grip unit was tested as well as the side window instrument. The pistol grip unit provided by the manufacturer had the high range GM tube positioned wrong and new calibration points had to be obtained for this instrument. Table 3 provides information on the instruments tested. Testing of NRC's ADM-300 started in Jul 91 and was concluded in Sep 91.



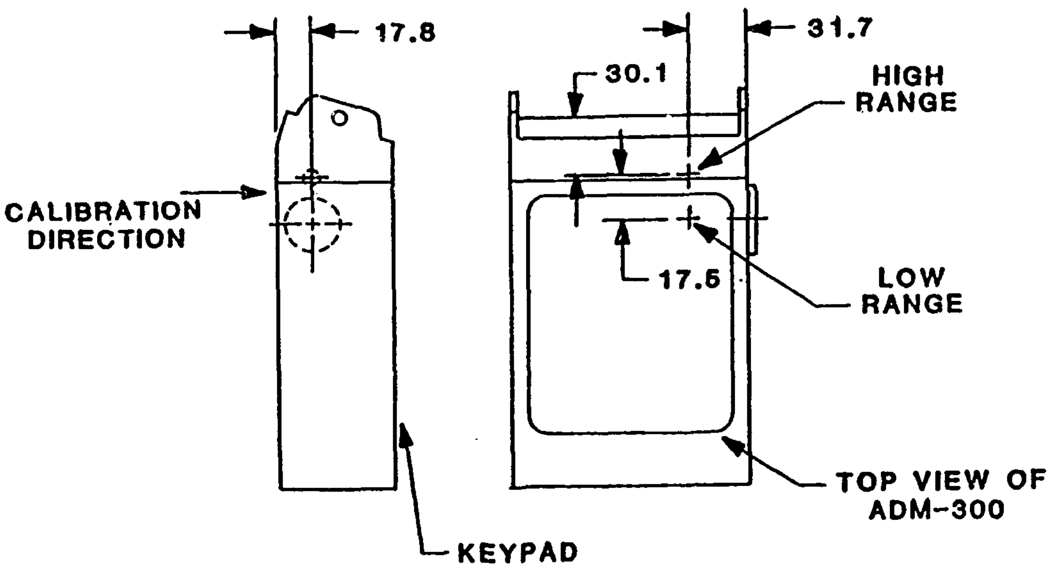


Figure 1. ADM-300 with the GM tubes and beta window located along the side of the unit. Lower figure illustrates the calibration points for the instrument.

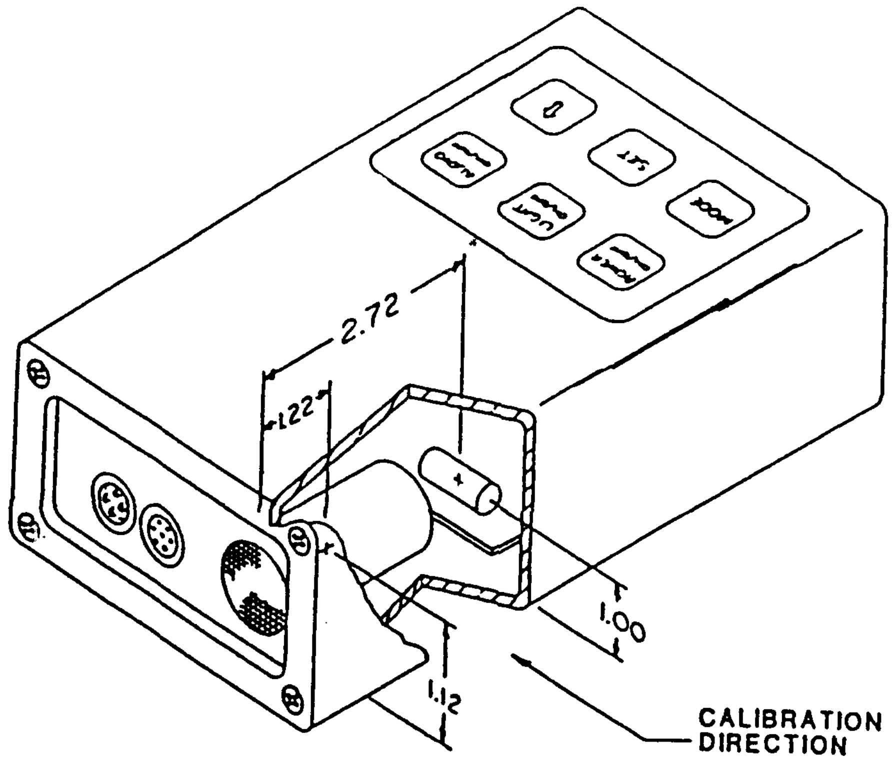


Figure 2. ADM-300 with GM tubes and beta window located along the bottom of the unit. Calibration points for this instrument are also illustrated.

TABLE 3. NRC INSTRUMENTS TESTED

NRC Model Number	Serial Number	Position of Beta Window
ADM-300	SM-094404	Side
ADM-300	SM-094405	Side
ADM-300	E-001	Bottom

Procedures

Radiation Testing

Radiation testing of the ADM-300 was conducted at AL/OEBSD's ICF using cesium (Cs-137), x-ray, californium (Cf-252), and various check sources. For higher exposure rates than capable with the Cs-137 sources, a Co-60 irradiator was used. Generally, the ADM-300 was set up on the test stand so that the calibration point as specified in the ADM-300 Operator's Manual was aligned towards the source. Instrument test results were observed on a video camera and recorded on standard forms. In all instances except when using check sources, the exposure rate was confirmed using an off-axis ion chamber calibrated at NIST against a primary standard.

When check sources were used, they were placed into contact with the surface of either the metal cover of the GM tube or on the screen covering the GM tube on the ADM-300. Each check source used is traceable to NIST and its activity was decay-corrected before use.

Two instruments provided by AL/OEBSC were used for this testing. At least four readings were taken for each test, and the average result was provided. The standard deviation was not always provided by the ICF with these data, however.

Environmental Testing

To provide a standard geometry for the pistol grip unit, a check source was secured to the ADM-300 by removing the screws holding its base plate and attaching a wire mesh over the bottom of the instrument. Since the pistol grip unit uses a sliding beta shield, the shield was slid up against the source to wedge it against the bottom portion of the base plate. This held the source close to the opening of the window.

The pistol grip ADM-300 was the only instrument submitted to environmental testing. At least four readings were taken for each test, and the average result was provided. The standard deviation was also determined for each test cycle.

RESULTS AND DISCUSSION

General

ANSI N42.17A covers the entire response of an instrument with procedures established by consensus agreement. Table 4 provides a summary of the radiation test results in accordance with the ANSI standard and Table 5 provides a summary of the radiation test results in accordance with the reference data from the technical orders for the AN/PDR-27 (3) and the AN/PDR-43 (4). It should be noted that just because the instrument failed an ANSI standard test does not mean the instrument doesn't perform better than the AN/PDR-27 or the AN/PDR-43. In some instances this failure could be due to the limitations of the standard itself.

General Characteristics

Units of Readout

The AMD-300 has the capability of providing a number of reading on its 2 X 16 LCD. For the exposure rate, the units are in roentgen per unit time (i.e., μR/hr, μR/min, mR/hr, mR/min, R/hr, R/min) to cover the 9 decades of unit operation. However, instead of providing units of dose (i.e., rads or grays), the dose function of the ADM-300 provides units of exposure over a preset time period (i.e., μR, mR, R). ANSI N42.17A, paragraph 4.1.1, states that readings of *photon* exposure and exposure rate instruments may be expressed in terms of exposure or exposure rate (e.g., mR, mR/hr, etc.). When using the ADM-300's "dose" function, the ADM-300 reported readings in units of "roentgen - dose." Since by definition the roentgen is only applicable to x-ray and gamma exposures in air, it was unclear as to what actually is being reported when measuring beta radiation. The alarm function for both the exposure rate and dose is a separate mode on the ADM-300. Their set points are also given in terms of exposure units on the display (e.g., mR/hr, mR, etc.). Units of dose equivalent are not used for either function.

Scaling Factors

The digital display shows the numeric value in three digits, the units of exposure, the mode the instrument is being used in, and an indication whether the alarm/audio has been activated. Below this display is a quasi-logarithmic analog scale covering the entire 9 decades of range (i.e., 10 μR to 10,000 R). The ADM-300 also has a scaler mode that one can set for a specified period of time. During the time interval, the display will indicate the total accumulated exposure on the top scale and the exposure rate on the lower scale. At the end of that time interval, an audible alarm will sound, and the total accumulate exposure will be displayed. The instruments tested pass the requirements of ANSI N42.17A, section 4.2.1.

TABLE 4. RESULTS OF RADIATION TESTING COMPARED TO ANSI N42.17A

Description	ANSI N42.17A Criteria	Result	Comment
General Characteristics			
Units of Readouts	4.1	Pass	Dose function expressed in terms of exposure
Scaling Factors	4.2	Pass	
Ease of Decontamination	4.3	Pass	
Moisture Protection	4.4	No Test	
Alarm Threshold	4.5	Pass	
Markings	4.6	Fail	Location of effective centers not marked
Battery Status Indicator	4.7	Pass	Low battery indication provided only
Protection of Switches	4.8	Pass	
Zero Set	4.9	Pass	
AC Power	4.10	No Test	
Battery Power	4.11	Pass	Max 3.1% decrease
Battery Power Indicator	4.12	Pass	Max 3.8% decrease
Electronic and Mechanical			
Alarm Reset	5.2.2.1	Pass	
Alarm Activation Delay	5.2.2.2	Fail	Exposure from delay exceeds 10 mrem for fields > 1.3 R/hr
Alarm Threshold Drift	5.2.2.3	No Test	
Stability	5.3	Pass	Max 3.4% decrease
Geotropism	5.4	Pass	Max 1.6% increase (See Table 9)
Response Time	5.5	Pass	
Coefficient of Variation	5.6	Pass	Individual instrument max 4.0%; between two instruments max 16%

TABLE 4. RESULTS OF RADIATION TESTING COMPARED TO ANSI N42.17A (cont)

Description	ANSI N42.17A Criteria	Result	Comment
Radiation Response			
Accuracy	6.1	Fail	1 μR/hr - 2000 R/hr < 5% @ 8000 R/hr > +27% (See Table 11 and Fig. 4)
Probe Surface Sensitivity	6.2	No Test	
Photon Energy Response	6.3	Fail	Over response @ 120 keV Under response @ 140 keV (See Table 12 and Fig. 5)
Beta Energy Response	6.4	No Test	ISO 6980-1981, Series 1 source set not available Detected beta > 224 keV (See Table 14 and Fig. 6)
Neutron Energy Dependence	6.5	No Test	
Photon Radiation Overload	6.6	No Test	
Angular Dependence	6.7	Fail	Pistol grip unit performed better (See Table 15)
Interfering Responses			
Extracameral Response	7.1	No Test	
Radio Frequency Fields	7.2	No Test	
Microwave Fields	7.3	No Test	
Electric Fields	7.4	No Test	
Magnetic Fields	7.5	No Test	
Interfering Ionizing Radiations	7.6	Pass	Both alpha and neutron

TABLE 5. RESULTS OF RADIATION TESTING COMPARED TO REFERENCE DATA FOR THE AN/PDR-27 AND AN/PDR-43

Item	AN/PDR-27 AN/PDR-43 Criteria	Result	Remarks
Range	0 - 500 R/hr	Pass	Observed range 0 - 8,000 R/hr
Scales	Four/Three	NA	Autoranging
Power	50 hours of continuous operation	Pass	>216 hours of continuous ops
Accuracy	± 20% from 10% full scale on each range 0-500 R/hr	Pass	1 μR/hr - 2,000 R/hr less than 5%
Gamma Energy Range	± 20% from 80 keV to 2 MeV	Fail	Overresponse at 120 keV; Underresponse at 140 keV
Beta Radiation	Detects beta radiation	Pass	Detected beta > 224 keV
Battery Check	Meter indication of battery condition	Pass	Low battery indication only

Ease of Decontamination

According to the manufacturer, the instrument is constructed to facilitate decontamination. The key pad surface uses membrane switches, and a smooth nonporous, external surface is provided for the instrument. Penetrations into the case are limited to the battery encasement and the ports for the external probe interface and the RS-232 cable. Both the battery case and the connectors for the external probe interface and the RS-232 cable are sealed to prevent ingress into the case. The coverings over the connector ports are rough and are close together making them difficult to remove, especially if the individual is in anticontamination gloves. Although the rough surfaces aid in gripping the covering caps, they could be difficult to decontaminate. The seams around the key pad membrane, the display section, the beta window, and the battery encasement may also cause problems in decontamination. The instruments tested pass the requirements of ANSI N42.17A, section 4.3.1.

Moisture Protection

The manufacturer's documentation states that the instrument is designed for immersion in water without leaking water into the unit. This was not tested under this protocol.

Alarm Threshold

The ADM-300 has two alarm features related to either the exposure rate (i.e., rate mode) or the total dose (i.e., dose mode) and are expressed in terms of exposure. The alarms can be set by the user and changed by the user, if so desired. The pressure key pads prevent inadvertent movement of the alarm threshold. The instruments tested pass the requirements of ANSI N42.17A, section 4.5.1.

Markings

The manufacturer's name, model number, and serial number, as well as the functional designation for the key pad membrane, are clearly marked and fixed to the unit. Through the testing process, the paint used on these markings rubbed off the instrument. The readout is digital and is readable from the normal operation position. The location of the effective centers of the GM detectors are not indicated on the instrument. The depth and location of these detectors are specified in the ADM-300 Operator's Manual. Since the effective centers of the GM tubes are not marked on the instrument, the instruments tested fail the requirements of ANSI N42.17A, section 4.6.1.

Battery Status Indication

The ADM-300 does not have a battery status indication but uses a test circuit to monitor the battery condition and display a low battery condition. The accumulated dose is stored in a nonvolatile memory. Additional accumulated dose will not be transferred to the memory once the low battery indication has been illuminated. The manufacturer's literature indicates that the unit has approximately 5 hours of battery life left after the low battery indicator has been illuminated. Our tests show a battery life of approximately 45 hours after the indicator was illuminated (Table 6). The instruments tested pass the requirements of ANSI N42.17A, section 4.7.1.

Protection of Switches

All switches are located under a key pad membrane. To activate a switch, one must press the switch until it clicks and keep pressing the switch before the switch will activate or deactivate. This should prevent inadvertent deactivation of a switch. The user must be aware of this feature, because one may assume after depressing the on/off switch that the instrument is turned off when it is still operational. The instruments tested pass the requirements of ANSI N42.17A, section 4.8.1.

Zero Set

All scales are automatically reset to zero and displayed on the readout once the cycle is started. The only function requiring zero setting is the dose mode. The user must depress two key pad switches to reset this function. At the end of this reset sequence, the dose is reset to zero and a clear dose message appears. The instruments tested pass the requirements of ANSI N42.17A, section 4.9.1.

AC Power

The units tested did not utilize any external AC power.

Battery Power

A Cs-137 check source was taped to the beta window of the two units undergoing radiation testing. The battery lifetime for both units operated in excess of 216.5 hours (Table 6). The final reading decreased from the first reading taken at t=0 (i.e., the reference reading) by less than 3.1%. The instruments tested passed the requirements of ANSI N42.17A, section 4.11.1, and exceed the reference data for the AN/PDR-27, the AN/PDR-43, and the Radiation Testing Protocol (Appendix A).

Battery Power Indicator

The low battery indication illuminated after 142.5 hours and before 166.5 hours into the battery power test (Table 6). The change from the reference reading is less than 4%. The instruments tested pass the requirements of ANSI N42.17A, section 4.12.1.

TABLE 6. BATTERY POWER TEST

Elasped Time (hours)	Mean Instrument Readings (mR/hr) # 094404	# 094405
0	90.1[a]	93.8[a]
1	91.2	92.2
2	89.1	93.0
24	89.6	92.0
54	91.0	91.9
72.5	90.0	92.5
142.5	90.6	92.0
166.5	90.5[b]	90.2[b]
191	90.0	91.1
216.5	89.1	90.9
238	Dead	Dead
Average	90.1	92.0
Std Dev	0.7	1.0
CV (%)	0.8	1.1

Percent Change from Reference:

	094404	094405
Low Battery	+0.4%	-3.8%
@ 216.5 hours	-1.1%	-3.1%

[a]Reference Reading

[b]Low Battery Indication

Electronic and Mechanical

Alarm Reset

The rate meter alarm mode on the ADM-300 was set at 30 R/hr and the instrument was exposed to a 38 R/hr field. The alarm activated properly and stayed activated for 5 minutes. There was no mechanism found to deactivate the audible alarm without interrupting the visual alarm. Once the exposure was terminated the instrument went back to background levels. The alarm had to be manually reset to terminate the alarm condition. The instruments tested pass the requirements of ANSI N42.17A, section 5.2.2.1.

Alarm Activation Delay

The time required before the alarm activated following exposure averaged 2.8 ± 0.17 seconds (Table 7). The audio alarm seemed to activate before the instrument had the opportunity to provide the visual display. This delay is due to a built-in time lag to update the display every 2 seconds. Assuming the alarm activation delay is fixed between each successive delivered radiation exposure, an exposure rate greater than 1.3 R/hr will result in an exposure to the individual in excess of the 10 mrem. Because of this, the instruments tested did not pass the requirements of ANSI N42.17A, section 5.2.2.2 and the Radiation Testing Protocol (Appendix A).

TABLE 7. ALARM ACTIVATION DELAY

Delivered Exposure (mR/hr)	Alarm Activation Time (Sec) Average	SD	CV(%)	Exposure Due to Delay (mR)
58.4	3.10	0.04	1.35	0.05
5,840	2.38	0.10	4.22	3.86
9,110	2.74	0.09	3.28	6.93
37,800	2.91	0.16	5.54	30.6[a]

[a]The delivered exposure to exceed the 10 mR/hr exposure ANSI criterion due to activation delay is 13,490 mR/hr.

Stability

A Cs-137 check source providing approximately 90 mR/hr was taped to the beta window of the two units undergoing radiation testing. The data collected over the 3-hour period show a maximum drift of -3.4% from the reference reading (Table 8). The instruments tested pass the requirements of ANSI N42.17A, section 5.3.1 and the Radiation Testing Protocol (Appendix A).

TABLE 8. STABILITY TEST RESULTS

Time (min)	Mean Instrument Readings (mR/hr)	% from Initial
SN 094405		
0	92.5	0
30	91.9	-0.6
60	90.3	-2.4
90	89.4	-3.4
120	90.3	-2.4
150	90.5	-2.2
180	90.5	-2.2
SN 094404		
0	86.7	0
30	86.4	-0.3
60	85.2	-1.7
90	88.0	+1.5
120	86.6	-0.1
150	84.0	-3.1
180	86.0	-0.8

Geotropism

The pistol grip and side beta window *units* were both tested for geotropism. The instruments had a Cs-137 source taped to the unit as they were rotated through the various orientations specified in ANSI N42.17A (Fig. 3). The maximum change from the reference orientation (i.e., unit lying flat with the beta window pointing towards the source) is an increase of 1.6% for the pistol grip unit when it is pointed up towards the source and an increase of 0.9% for the side window unit when it is pointed down towards the source (Table 9). The instruments tested pass the requirements of ANSI N42.17A, section 5.4.1.

TABLE 9. GEOTROPISM RESULTS

Orientation	Average ADM-300 Reading		% Change from Ref	
(Degrees)	Pistol	Side Window	Pistol	Side Window
0[a]	270.8	112.0	NA	NA
90	274.3	112.0	+1.29	0.0
180	273.0	111.3	+0.83	-0.67
270	272.5	111.5	+0.65	-0.45
Down	269.5	111.0	-0.46	+0.89
Up	275.0	111.3	+1.57	-0.67

[a]Reference orientation

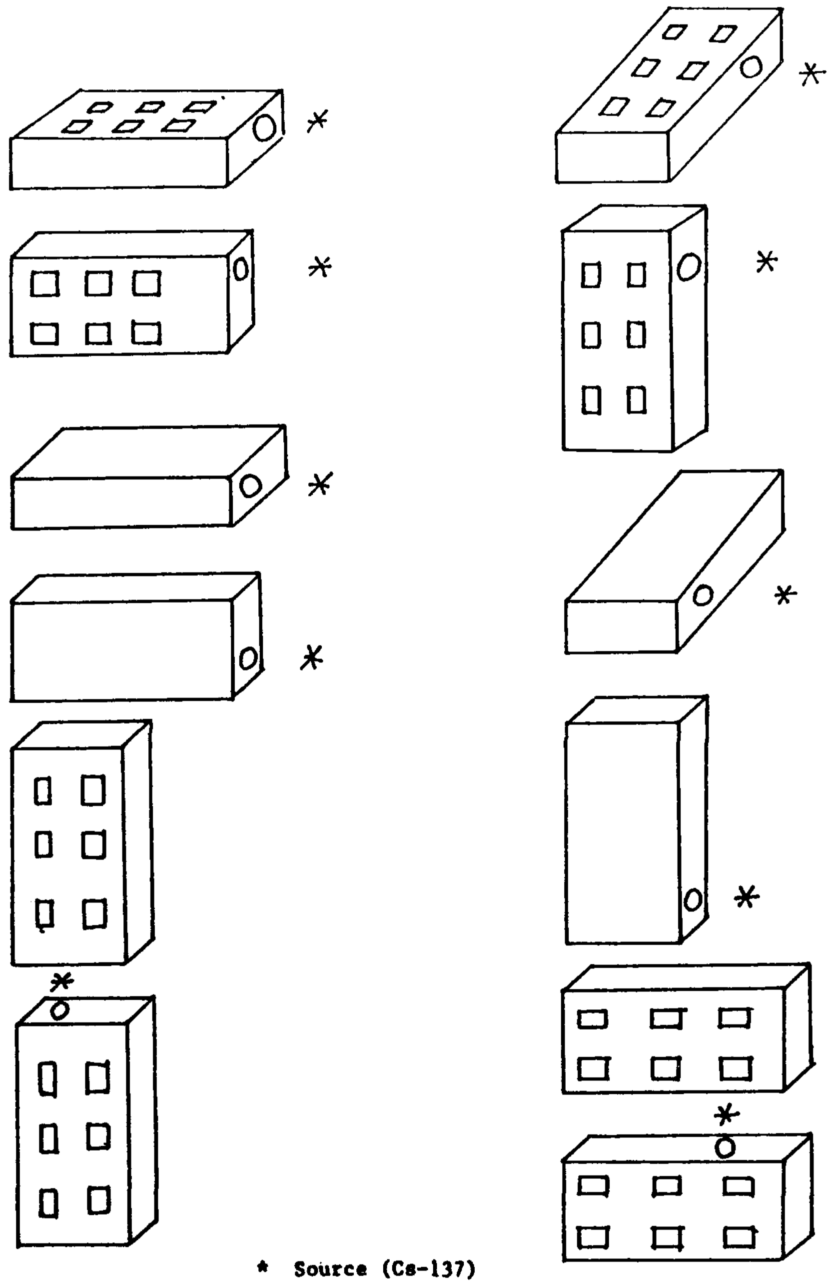


Figure 3. ADM-300 orientation for ANSI N42.17A geotropism test.

Response Time

Since the instrument is a digital instrument, the response time should be instantaneous. The manufacturer's literature indicates the response time is 2 seconds in a field above 1 R/hr and below 5 seconds in a field less than 1 R/hr. The ADM-300 updates the display approximately every 2 seconds, regardless of the radiation field that is being measured. Using a 5 R/hr radiation field, the unit's response was within the first update of the display (i.e., within 2 seconds). The instrument in the ratemeter mode appeared to overrespond slightly to the radiation field, but stabilized within two display updates (another 4 seconds). When the radiation source was removed, the unit went back to background within 2 seconds or one display update. Using a 50 mR/hr radiation field, the unit's response was within 4 seconds or two screen updates. Again the unit appeared to overrespond slightly but was stable within another 4 seconds or two display updates. When the radiation source was removed, the unit went back to background within 4 seconds or two display updates. The instruments tested pass the requirements of ANSI N42.17A, section 5.5.1, and the Radiation Testing Protocol (Appendix A).

Coefficient of Variation

Individual Instruments

The ADM-300 instruments were exposed to various radiation fields from 760 μR/hr to 38 R/hr (Table 10). Twenty independent readings, as required by ANSI N42.17A, were taken only when the instrument was exposed to the 760 μR/hr radiation field. The coëfficient of variation (CV) varied from 0.2% to slightly more than 4%. To determine the CV over a long period of time, the data from the battery power test were used. For these data, the CV over the entire life of the batteries is less than 1.2%. The instruments tested pass the requirements of ANSI N42.17A, section 5.6.1, and the Radiation Testing Protocol (Appendix A).

Radiation Response

Accuracy

Over the range of 1 μR/hr to 2,000 R/hr, tests showed the accuracy of the delivered units was less than 5% (Table 11 and Fig. 4) and well within the requirements of ANSI N42.17A, section 6.1.1; the reference data for the AN/PDR-27 and the AN/PDR-43 (Table 1); and the Radiation Testing Protocol (Appendix A). A Cs-137 source was used between 1 μR/hr to 38 R/hr for the two instruments tested. A Co-60 source was used for 2,000 R/hr and 8,000 R/hr exposures, but only one instrument was tested at these high exposure rates. At 8,000 R/hr, the ADM-300 unit that was tested had an overresponse of 26.8%, and the low range GM tube burned out. The reason for the failure of this tube was not investigated. This overresponse at 8,000 R/hr exceeds the requirements of ANSI N42.17A, section 6.1.1, and the Radiation Testing Protocol (Appendix A).

The manufacturer's literature states, "The ADM-300 can be self-calibrated using a license free source (less than 10 μCi Cs-137)." However, the Operator's Manual recommends that the low and high range GM tubes be calibrated at 100 mR/hr and 400 R/hr for good statistical accuracy. To perform the accuracy test for the high radiation fields, the initial calibration of the unit provided a gross underresponse, and the unit had to be recalibrated with a 400 R/hr source to get reliable data.

TABLE 10. COEFFICIENT OF VARIATION

Reading Number	μR/hr 404	μR/hr 405	mR/hr 404	mR/hr 405	R/hr 404	R/hr 405	R/hr 404	R/hr 405
1	754	759	49.5	56.8	10.1	6.49	40.9	26.8
2	751	760	48.8	56.3	9.68	6.68	40.7	27.2
3	758	755	49.7	57.5	9.42	6.57	40.8	28.3
4	759	753	49.2	57.0	10.3	6.53	40.9	28.1
5	764	751	—	—	—	—	—	—
6	761	756	—	—	—	—	—	—
7	762	753	—	—	—	—	—	—
8	761	762	—	—	—	—	—	—
9	756	761	—	—	—	—	—	—
10	755	759	—	—	—	—	—	—
11	754	752	—	—	—	—	—	—
12	750	756	—	—	—	—	—	—
13	747	757	—	—	—	—	—	—
14	757	761	—	—	—	—	—	—
15	759	755	—	—	—	—	—	—
16	756	754	—	—	—	—	—	—
17	757	757	—	—	—	—	—	—
18	762	756	—	—	—	—	—	—
19	755	753	—	—	—	-	—	—
20	753	756	—	—	—	—	—	—
Avg	756.6	756.3	49.3	56.9	9.88	6.57	40.8	27.6
SD	4.38	3.20	0.39	0.50	0.40	0.08	0.10	0.72
CV(%)	0.58	0.42	0.79	0.87	4.03	1.25	0.23	2.60

TABLE 11. ACCURACY OF ADM-300

Exposure Delivered	Average Response	Ratio Cal Point
852 μR/hr	868 μR/hr	1.019
58.4 mR/hr	56.9 mR/hr	0.974
220 mR/hr	215.0 mR/hr	0.977
920 mR/hr	909.5 mR/hr	0.989
5,840 mR/hr	6,373 mR/hr	1.091
9,110 mR/hr	9,880 mR/hr	1.084
37.8 R/hr	40.8 R/hr	1.080
1,980 R/hr[a]	2,065 R/hr	1.043
7,980 R/hr[a]	10,120 R/hr	1.268

[a]Irradiated with Co-60 instead of Cs-137

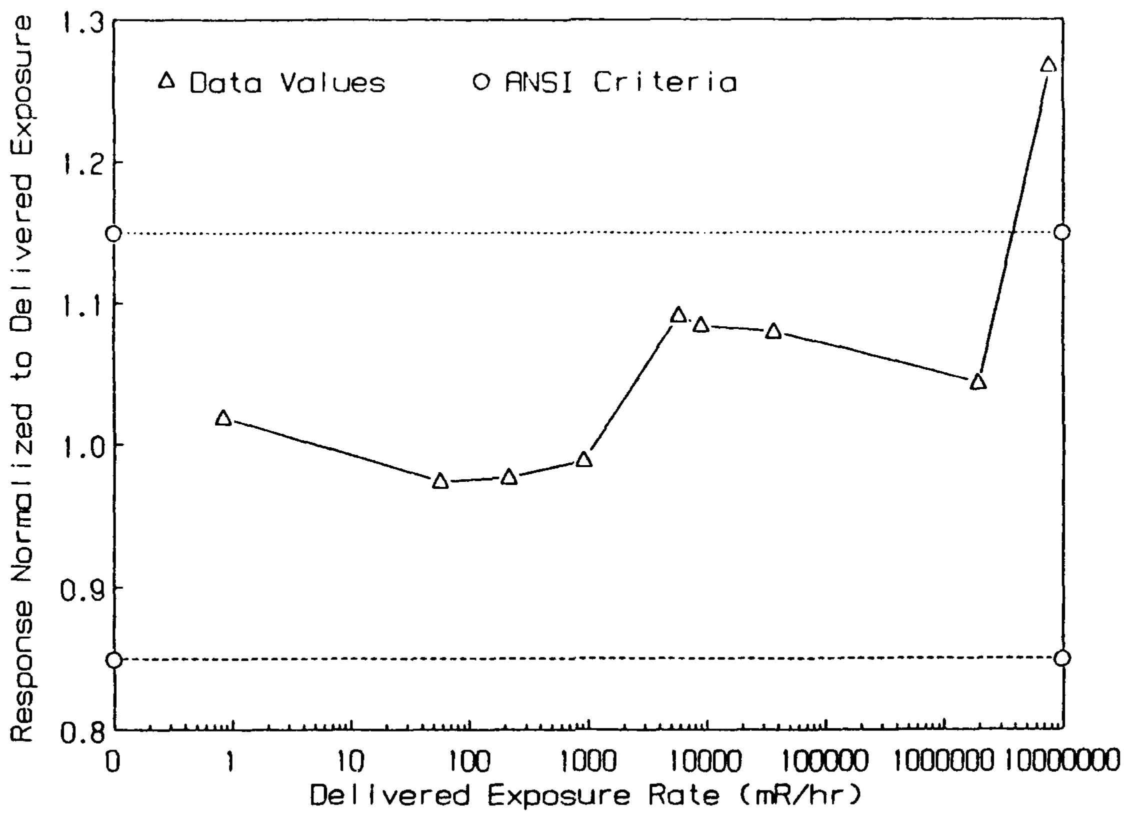


Figure 4. Accuracy test results of ADM-300.

Photon Energy Response

The response of the ADM-300 to various radiation fields is shown in Table 12 and graphically presented in Figure 5. In each situation, the ADM-300 was irradiated through the calibration point as indicated in the Operator's Manual and at a rate where there was no rate effect present (i.e., between 800 µR/hr and 1,980 R/hr). The response is within ± 11 percent for the energies of 80 keV, 252 keV, 662 keV, and 1,250 keV. However, using NIST x-ray method H-150 for 120 keV exposure as specified in Table 6 of ANSI N42.17A, the change in response from the Cs-137 reference value increased to 138%. This fluctuation is outside the requirements of ANSI N42.17A, section 6.3.1; the reference data for the AN/PDR-27 and AN/PDR-43 (Table 1); and the Radiation Testing Protocol. Since the ICF was limited in the number of H-series filters, the performance at 40 keV (NIST beam code H50) as specified in the Radiation Testing Protocol could not be done. However, the NIST beam codes with the M-series filters was substituted allowing testing at effective energies of 51 keV, 70 keV and 140 keV. Using the NIST beam code M-250, the energy response from the Cs-137 reference value dipped 73%. Below 80 keV with the beta window closed, the instrument response fell off drastically and does not comply with the "should" requirement of this section to have an effective energy range as low as 20 keV, but does comply with the "shall" requirement of the standard to have an effective energy range as low as 80 keV. With the beta window open, the ADM-300 could "see" the 60 keV x-ray from an Americium 241 check source and the low energy emissions from a Cs-137 check source. Dr. Sudhakar Pandey, Vice President of Engineering for NRC, (telephone interview, 24 Feb 92), indicated that this type of response is typical for models built for the European Community. For those instruments, all readings were reported in terms of dose equivalent employing the quality factor for photons as *defined by the International Commission on* Radiological Protection (6). Because this quality factor rises above one for low energy photons, the shielding for the detector tubes was slit to enhance its response at low energies.

NRC provided AL/OEBS with a copy of a preproduction test report for the ADM-300 as being purchased by the Swedish Defence Martiel Administration.[1] In this report, several energy dependence tests were performed over a "low" exposure and a "high" exposure range. The average response of the instruments tested, using the combined data from these exposure ranges, exceeds the criteria of ANSI N42.17A at 178, 222, and 1,250 keV. Because of this, additional testing of the photon energy response of the ADM-300 is warranted.

TABLE 12. PHOTON ENERGY DEPENDENCE

Source or NIST Procedure	Effective Energy (keV)	Delivered Exposure (mR) Avg	SD	ADM-300 Reading (mR) Avg	SD	Ratio	% from Ref
M-100	51	3,860	8.1	1,349	9.0	0.349	-65
M-150	70	5,438	10.9	1,385	2.6	0.255	-74
H-100	80	2,780	37.8	3,000	[a]	1.079	+9
H-150	120	1,315	39.2	3,138	16.9	2.358	+138
M-250	140	2,776	44.4	736	0.5	0.265	-73
H-300	252	18.4	[a]	21	1.3	1.141	+16
Cs-137	662	920	[a]	910	2.1	0.989	0
Co-60	1,250	1,980[b]	[a]	2,065[b]	7.0	1.043	+6

[a]Even though several instrument readings were taken, only the average result was reported by the calibration facility.

[b]These readings are in R not mR. This result may be a rate effect instead of an energy effect. Using a higher flux, the ratio using Co-60 is 1.268, and the change from reference (Cs-137) is +28%.

[1] Test Report ADM-300 - Pre-production Test Report, Nuclear Research Corporation, Warrington PA (16 Apr 90).

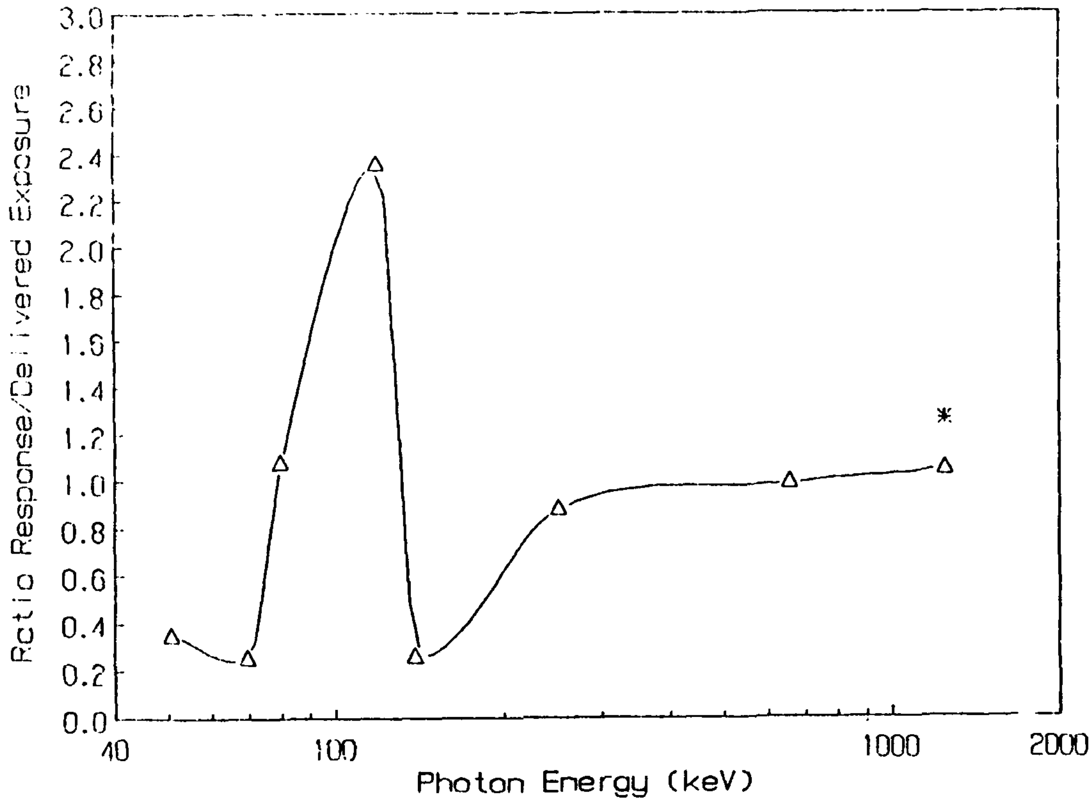


Figure 5. Photon Energy Response of ADM-300.

TABLE 13. PHOTON ENERGY RESPONSE USING CHECK SOURCES[a]

Source	Serial Number	Energy (keV)	Exposure Rate µR/min	ADM-300 Reading (µR/min) Window Open Avg	Window Open Ratio	Window Closed Avg	Window Closed Ratio
Am-241	2Q154	60	174.8	90.1	0.515	0.0	---
Ba-133	2R154	356	187.3	149.8	0.800	29.2	0.156
Cs-137	2S376	662	375.7	1,487.5	3.959	75.5	0.201
Mn-54	2V294	835	11.1	5.0	0.450	3.2	0.288
Co-60	2U338	1,250	997.0	336.8	0.338	254.9	0.256
Na-22	2X167	1,274	469.5	209.5	0.446	103.3	0.220

[a]Source placed into direct contact with the beta window or the window covering.

Beta Energy Response

Since the ISO 6980-1984, Series 1, source set was not available for this testing, the protocol established in ANSI N42.17A, Section 6.4, could not be followed. Dr.

Sudhakar Pandey, Vice President of Engineering for NRC, (telephone interview, 27 Feb 92) stated that, because of geometry constraints in measuring beta, the ADM-300 was designed to detect beta only, and the units on the display for the ADM-300 were only "relative units" at best. To determine this relative response, the absorbed dose in air for several beta check sources was compared to the response on the unit (Table 14 and Fig. 6). The unit could easily detect beta energies greater than Pm-147 (225 keV). The instruments tested pass the requirements of the reference data for the AN/PDR-27 and the AN/PDR-43 (Table 1) and the Radiation Testing Protocol but appears to fail the requirements of ANSI N42.17A, section 6.4.1. This test should be repeated when the ISO 6980-1984, Series 1 source set becomes available.

TABLE 14. BETA ENERGY DEPENDENCE

Source	Max Energy (keV)	Delivered Dose (air) (µrad/hr)	Average[a] Relative Reading	Ratio Reading/ Delivered
C-14	156.5	1,094.3	8.3	0.0076
Pm-147	224.7	4.1	6.1	1.50
Tc-99	293.6	104.2	127.7	1.23
Cl-36	709.6	358.8	702.3	1.96
Pb-210	1,161.4[b]	209.3	1,063.0	5.08
Sr-90	2,283.9[c]	268.9	1,653.0	6.15

[a] The displayed units on the ADM-300 are considered "relative units." (Dr. Sudhakar Pandey, telephone interview, 26 Feb 92)

[b] Pb-210 has two betas with max energies of 16.5 keV and 63.0 keV. This decays into Bi-210 with one beta at 1,161.4 keV as listed.

[c] Sr-90 has one beta at 546.0 keV and decays into Y-90 with one beta at 2,283.9 keV as listed.

Photon Radiation Overload

This test was not performed for the instruments. There was no source readily available capable of producing a rate of 100 times the highest decade (10,000 R/hr).

Angular Dependence

Since the two types of AMD-300 instruments tested had different configurations, an angular dependence test was performed on each type of instrument. Tests for angular dependence were only performed using a Cs-137 source. The notation "z-axis" represents a rotation about the z-axis of the unit or turn around on a flat surface, the notation "x-axis" represents a rotation around the x-axis or an end-to-end rotation, and the notation "y-axis" represents a rotation around the y-axis or a side-to-side rotation. Table 15 shows the angular dependence of these two types of units and the relative position of the unit at zero degrees. Neither type of unit passes the angular dependence requirements of ANSI N42.17A, section 6.7.1, for all axes of consideration.

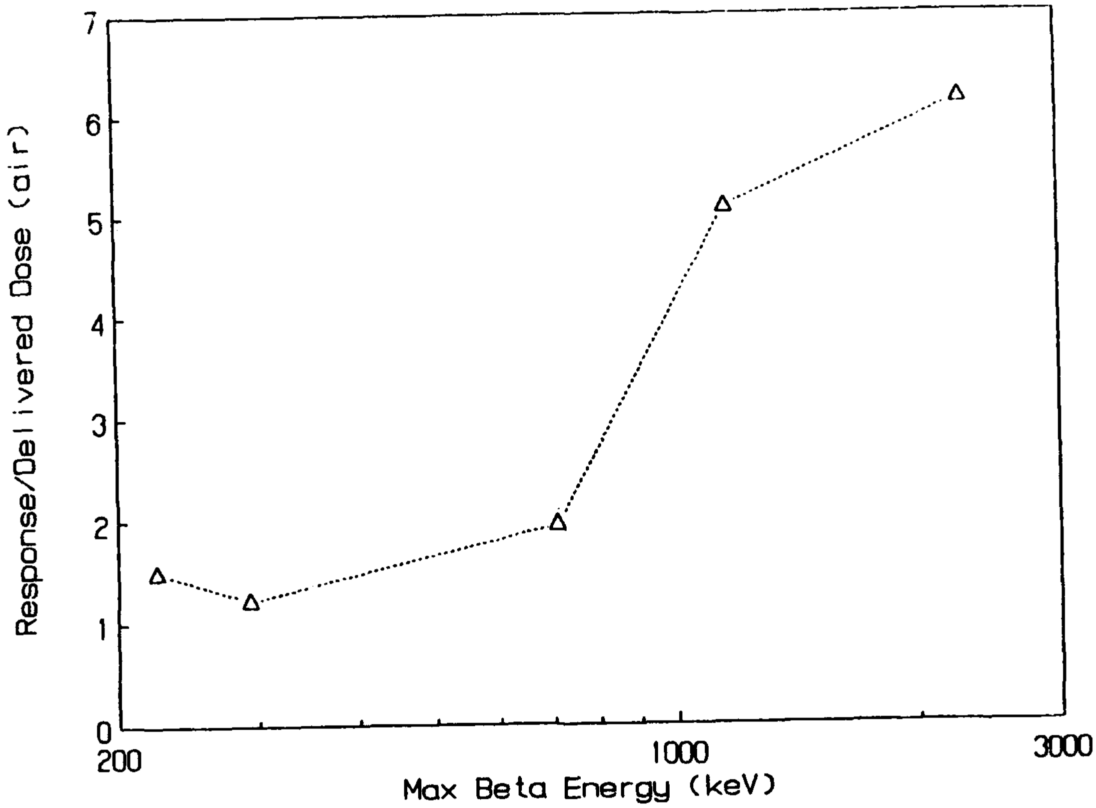


Figure 6. Beta energy response using check sources in contact with the beta window.

<u>Side Window Unit</u>

This type of unit only passed the ANSI N42.17A requirement at 45° from maximum in the z-axis rotation. For rotations in the x-axis and y-axis, the overall deviation from the maximum value was slightly below the requirement (i.e., 20.7% and 20.8% versus 20%). This unit passed the ANSI N42.17A requirement at 90° of rotation in the z-axis and y-axis. In the x-axis, the deviation at 90° from the maximum value was 71.6%, well above the requirement of ±50%. The maximum deviation (i.e., maximum value to minimum value) is 58.3% in the z-axis rotation, 71.6% in the x-axis rotation, and 47.7% in the y-axis rotation. As shown in Figures 7 through 9, the angular dependence pattern is a typical butterfly type of pattern. In all instances, the maximum deviation was found whenever the radiation had to pass through the majority of the electronics package to reach the detector.

TABLE 15. ANGULAR DEPENDENCE OF ADM-300

	Normalized to Delivered Exposure								% Diff from Max	
	0	45	90	135	180	225	270	315	@45°	@90°
Z-Axis										
Side Window Units										
Average	**0.990**	0.959	0.981	0.931	0.413	0.692	0.700	0.871	12.0	29.3
CV (%)	4.11	3.05	1.46	5.93	3.49	3.40	3.90	3.86		
Pistol Grip Unit										
Average	0.596	0.985	**1.055**	0.996	1.022	0.981	0.705	0.443	6.6	43.5
CV (%)	2.89	1.98	1.40	2.71	1.38	1.44	3.72	2.22		
X-Axis										
Side Window Units										
Average	**1.172**	1.093	0.333	0.981	1.103	1.034	0.955	0.929	20.7	71.6
CV (%)	9.53	0.00	4.48	0.00	15.6	12.6	6.83	16.0		
Pistol Grip Unit										
Average	**1.134**	1.084	0.691	1.070	1.044	0.899	0.814	1.021	10.0	39.1
CV (%)	2.61	3.52	1.88	3.44	3.24	2.52	3.51	0.77		
Y-Axis										
Side Window Units										
Average	1.006	0.936	0.536	0.901	**1.024**	0.792	1.023	0.969	20.8	47.7
CV (%)	0.69	1.33	6.96	0.43	0.00	1.17	2.51	4.96		
Pistol Grip Unit										
Average	1.106	1.048	0.455	0.992	**1.158**	1.074	1.054	1.069	14.3	60.7
CV (%)	3.98	6.90	4.18	2.27	2.15	2.84	3.14	3.58		

Bold numbers represent the maximum readings and were used as the references.

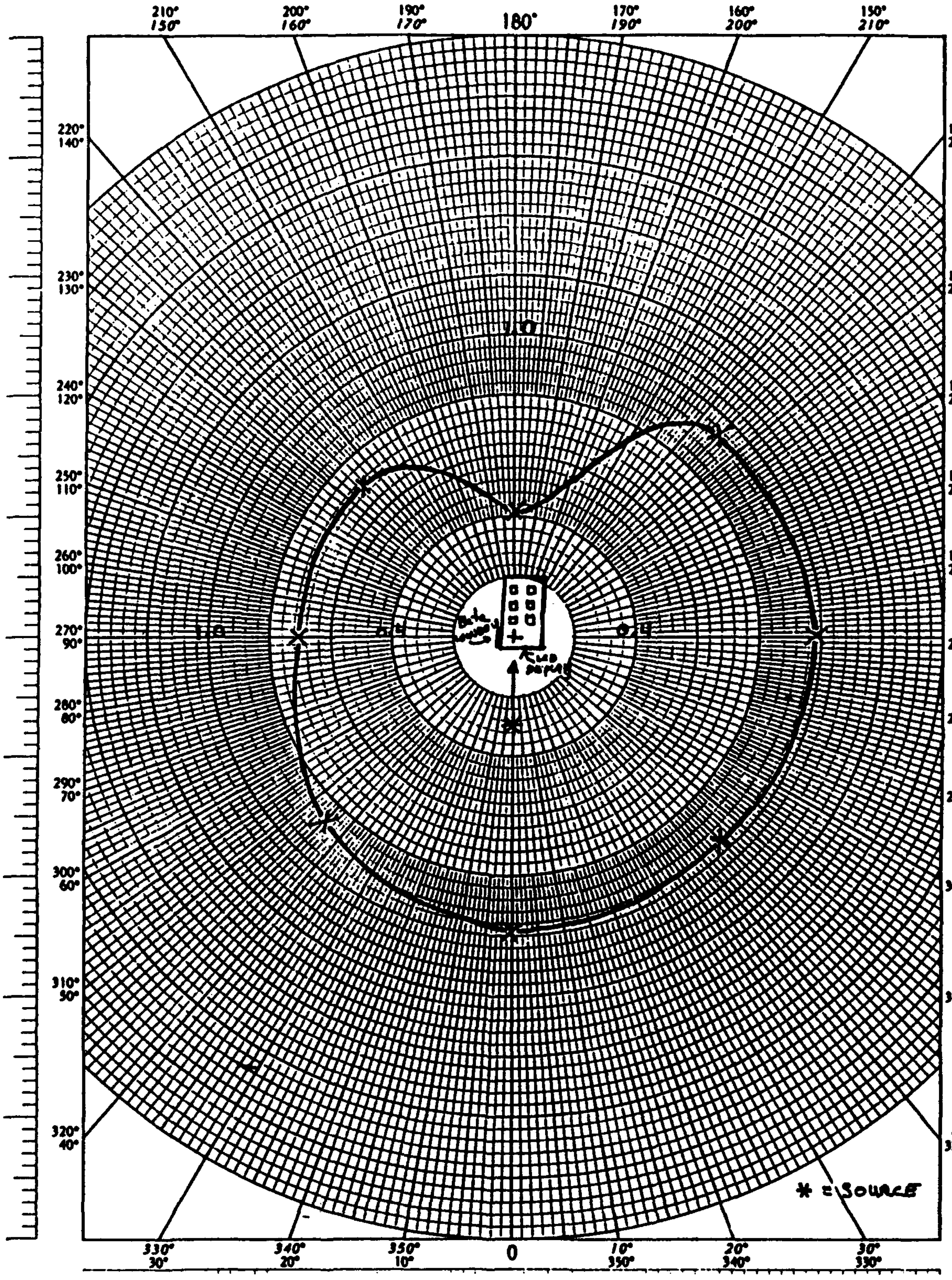


Figure 7. Angular response of side window ADM-300 rotated around the z-axis.

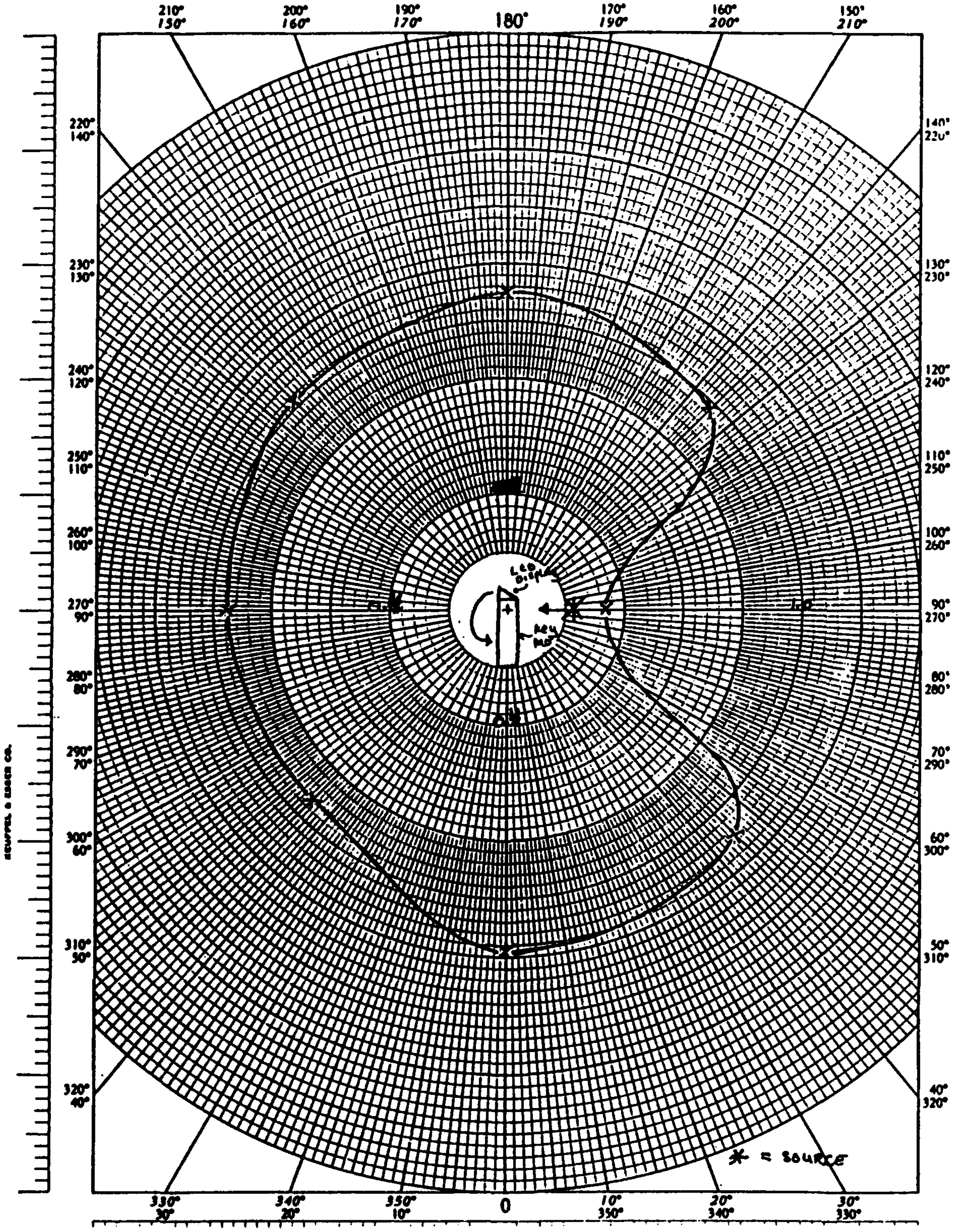


Figure 8. Angular response of side window ADM-300 rotated around the x-axis.

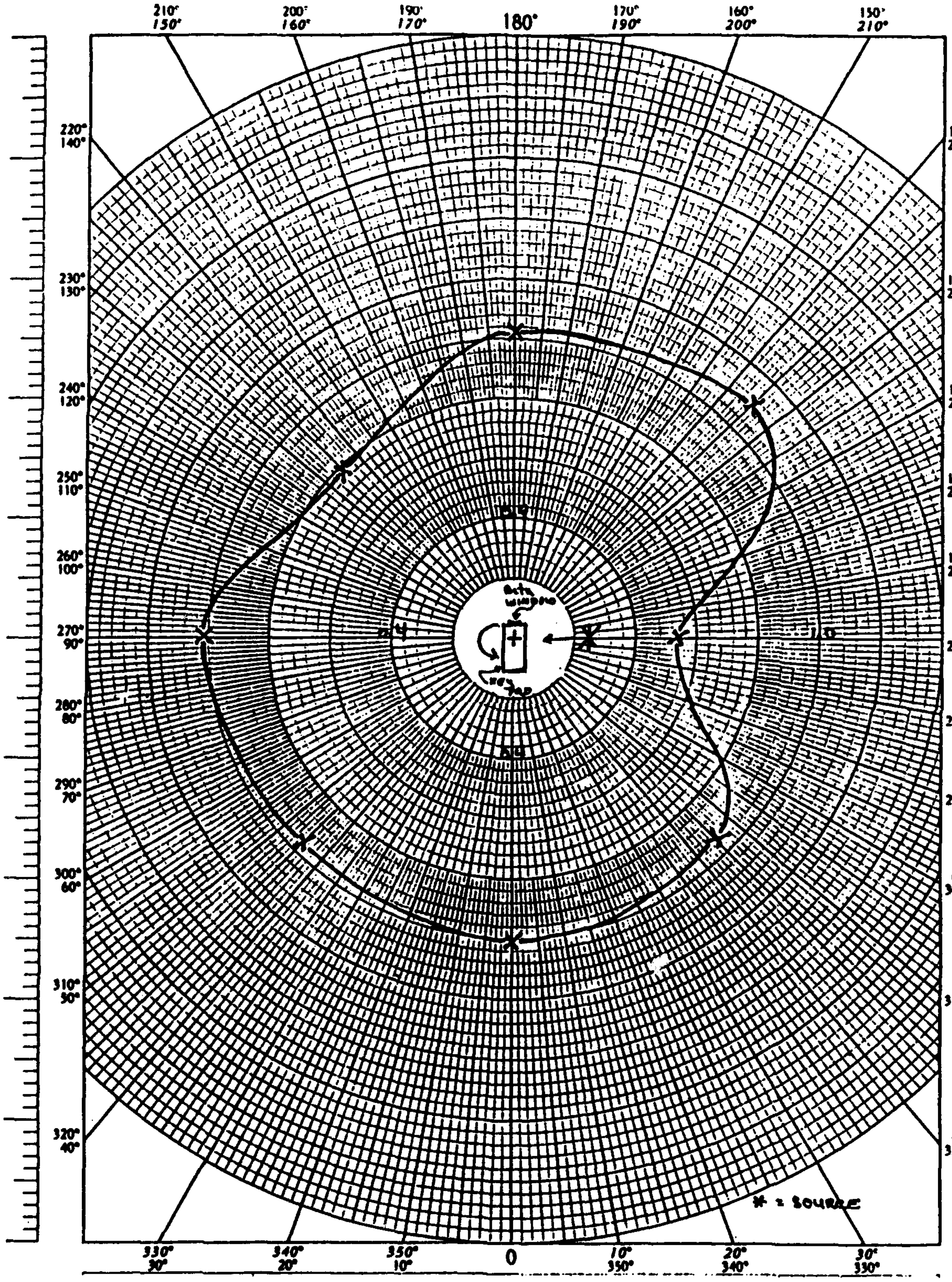


Figure 9. Angular response of side window ADM-300 rotated around the y-axis.

Pistol Grip Unit

This type of unit passed the ANSI N42.17A requirement at 45° from the maximum for all axes of rotation. The maximum deviation for this requirement was 14.3% in an y-axis rotation. This unit passed the ANSI N42.17A requirement at 90° from the maximum for rotation z-axis and x-axis. In y-axis, the deviation at 90° from the maximum value was 60.7%, well above the requirement of ±50%. The maximum deviation (i.e., maximum value to minimum value) is 58.0% for the z-axis rotation, 39.1% for the x-axis rotation, and 60.7% for an y-axis rotation. As shown in Figures 10 through 12, the angular dependence pattern for this unit is more rounded than the typical butterfly pattern. Only in an y-axis rotation is the butterfly pattern apparent. The maximum deviation was found whenever the radiation was attenuated by the electronics of the instrument or the battery pack.

Interfering Responses

The units were not tested for interfering responses from radiofrequency, magnetic, or electrostatic fields.

Neutron Interferences

A plutonium beryllium source producing 15 mrem/hour of fast neutrons and a Cf-252 source producing 8 mrem/hour did not produce a response in the unit above that normally expected with the gamma component being present. The photon exposure rate from the Cf-252 source was determined using a neutron insensitive detector and was subtracted from the exposure rate noted on the ADM-300. The instruments tested pass the requirements of ANSI N42.17A, section 7.6.1.

Alpha Interferences

The ADM-300 was exposed to a plutonium-239 source that produced 6,415.3 disintegrations per minute (DPM) ± 7.0%. The unit showed no response to alpha radiation even with the beta window open. The instruments tested pass the requirements of ANSI N42.17A, section 7.6.1.

Environmental Testing

General

All the environmental tests pass the general requirements of ANSI N42.17A, sections 8.1-8.7 (i.e., being within ± 15% of the true reading). Table 16 summarizes these results, and Table 17 provides a comparison of the test results with the reference data for the AN/PDR-27 and the AN/PDR-43. The following sections provide specific information on the test results.

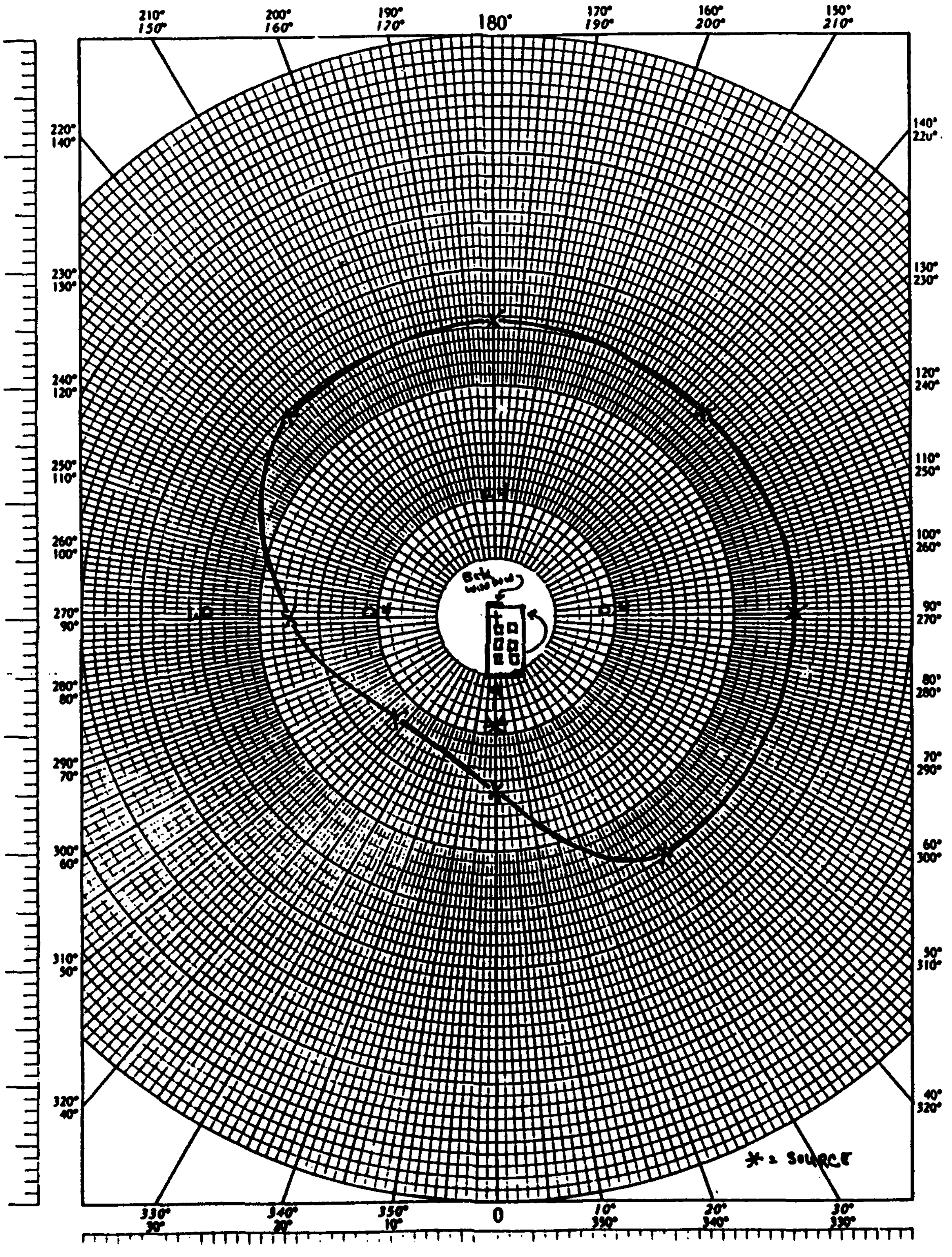


Figure 10. Angular response of end window ADM-300 rotated around the z-axis.

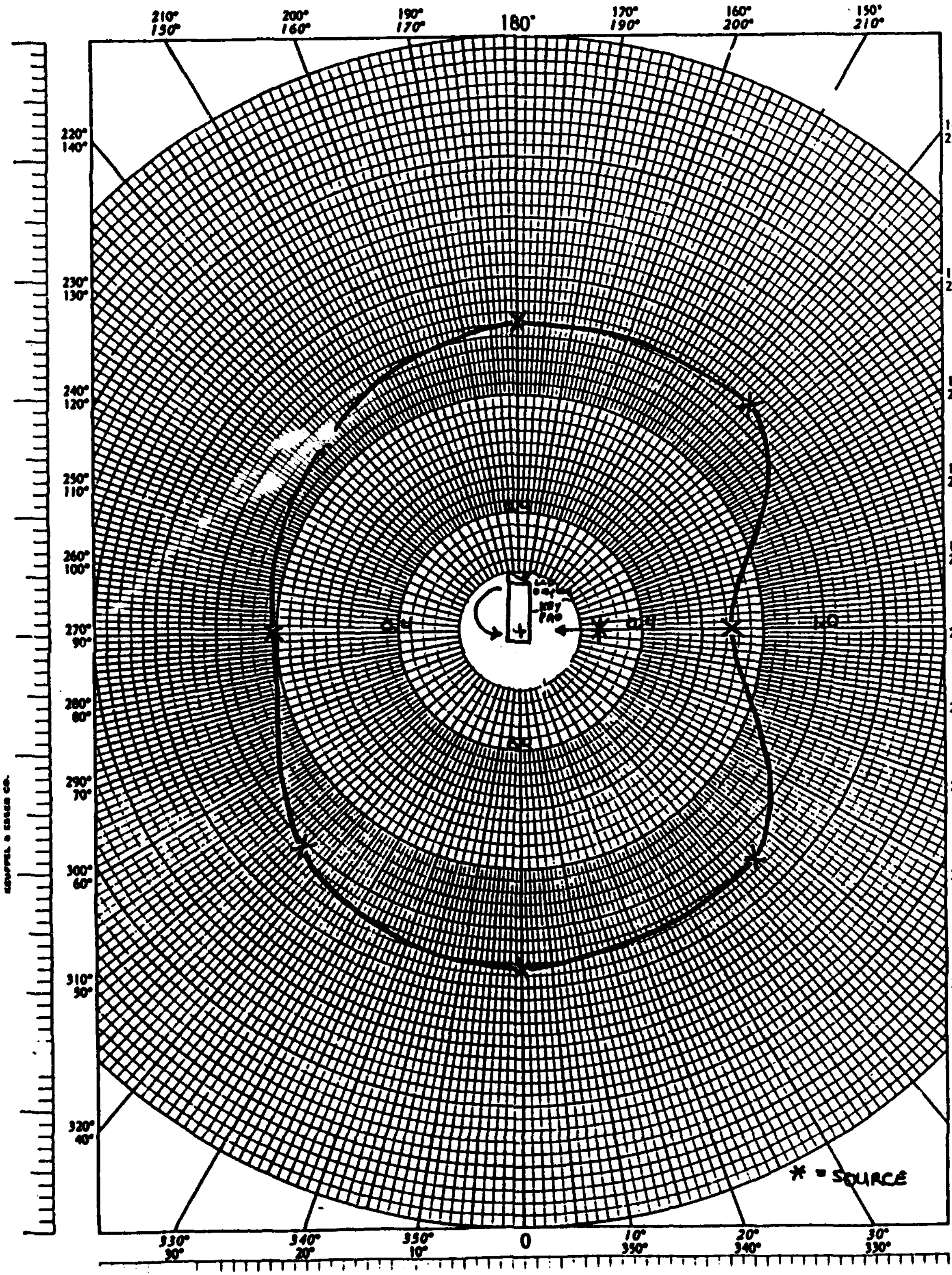


Figure 11. Angular response of end window ADM-300 rotated around the x-axis.

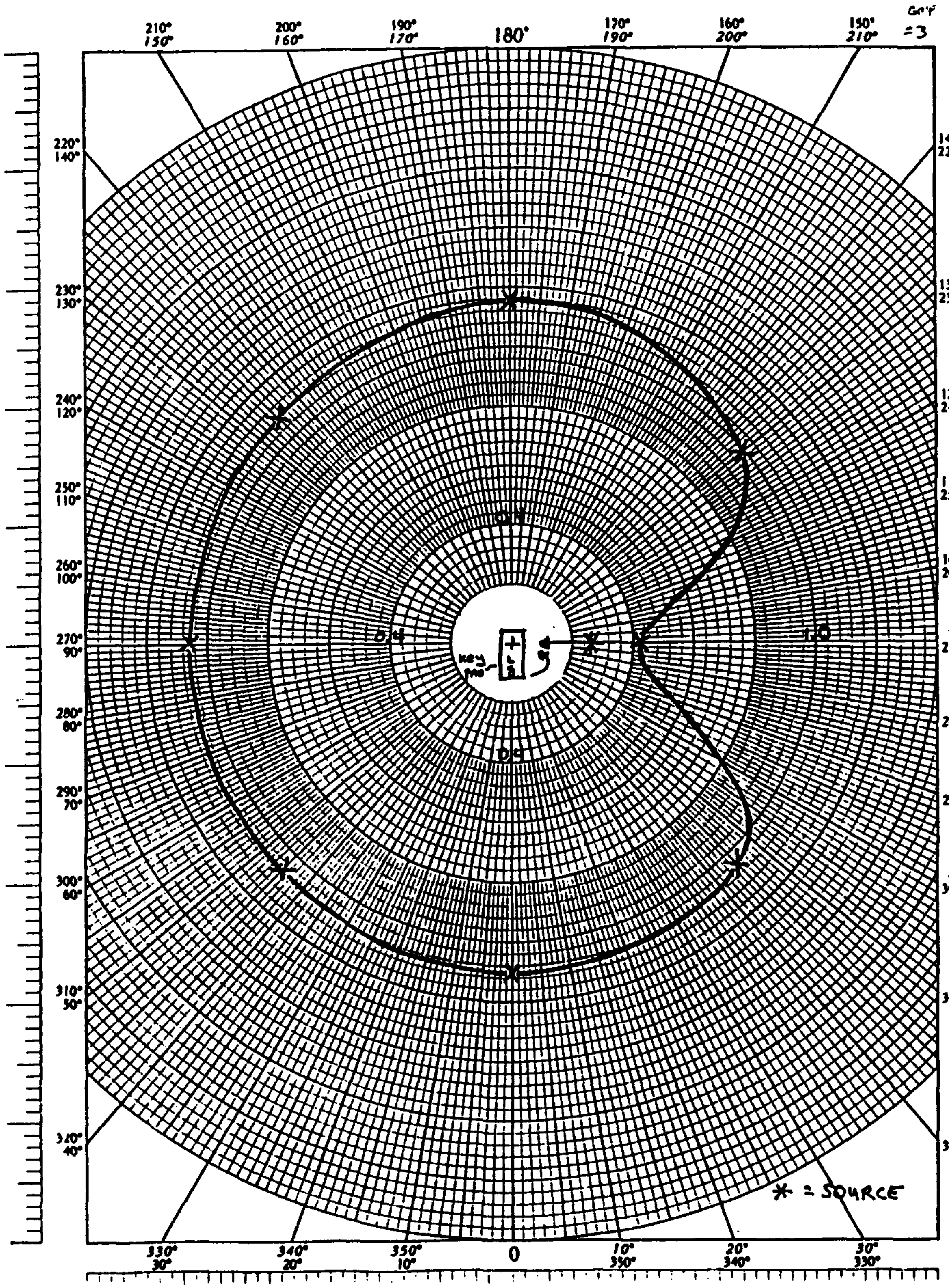


Figure 12. Angular response of end window ADM-300 rotated around the y-axis.

TABLE 16. RESULTS OF ENVIRONMENTAL TESTING[a]

(All results are in mR/hr)

Environmental Test	Ref Value Avg	Ref Value Std Dev	15% ANSI Criteria Max	15% ANSI Criteria Min	Test Values Avg	Test Values Std Dev	Results
Low Pressure (Storage)	233.8	2.8	268.8	198.7	233.0	1.8	Pass
Low Pressure (Operational)	232.4	2.9	267.2	197.7	230.5-241.0[b]		Pass
Low Pressure (Rapid Decompression)	233.3	4.0	268.2	198.3	231.5	1.3	Pass
High Temperature (Static)	237.1	3.4	272.7	201.6	235.4	1.7	Pass
High Temperature (Diurnal)[c]	–	–	–	–	–	–	–
High Temperature (Storage)	254.0	1.8	292.1	215.9	270.5	2.1	Pass
Low Temperature (Storage)	235.3	2.2	270.5	200.0	236.5	2.5	Pass
Low Temperature (Diurnal)	228.6	4.8	262.9	194.3	223.2-228.3[b]		Pass
Low Temperature (Static)	226.0	4.2	260.0	192.1	223.4	3.4	Pass
Temperature Shock (High Temp)	220.0	1.4	260.0	187.0	229.5	2.4	Pass
(@ Shock)	220.0	1.4	260.0	187.0	230.3	4.6	Pass
Temperature Shock (Low Temp)	232.0	0.8	266.8	197.2	222.0	1.8	Pass
(@ Shock)	232.0	0.8	266.8	197.2	223.5	4.7	Pass
Humidity Test #2 (Diurnal)	231.6	2.8	266.4	196.9	229.3-234.8[b]		Pass
Humidity Test (Static)	230.0	1.8	264.5	195.5	227.9	3.4	Pass
Vibration Sinusodial (x-axis)	233.5	2.7	268.5	196.5	233.4	2.2	Pass
(y-axis)	226.5	2.5	260.5	192.5	225.5	6.9	Pass
(z-axis)	222.5	1.3	255.9	189.1	226.0	2.5	Pass
Vibration Random (x-axis)	219.3	1.7	252.1	186.4	230.3	1.7	Pass
(y-axis)	219.8	1.5	252.7	186.7	217.8	3.0	Pass
(z-axis)	225.8	3.5	259.6	191.9	226.8	2.5	Pass

TABLE 16. RESULTS OF ENVIRONMENTAL TESTING (Cont.)[a]

(All results are in mR/hr)

Environmental Test	Ref Value Avg	Ref Value Std Dev	15% ANSI Criteria Max	15% ANSI Criteria Min	Test Values Avg	Test Values Std Dev	Results
Shock Test (Transit Drop)[c]	-	-	-	-	-	-	-
Shock Test (Bench)							
(Face one, Edge one)	227.5	1.3	261.6	193.4	230.3	1.0	Pass
(Face one, Edge two)	229.0	2.0	263.4	194.6	229.0	1.6	Pass
(Face two, Edge one)	227.8	1.0	261.9	193.6	234.3	1.5	Pass
(Face two, Edge two)	232.3	1.0	267.1	197.4	232.3	2.1	Pass
(Face three, Edge one)	231.8	2.2	266.5	197.0	230.3	1.5	Pass
(Face three, Edge two)	231.5	1.3	266.2	196.8	231.5	1.9	Pass
(Face four, Edge one)	236.5	1.9	272.0	201.0	237.8	1.5	Pass
(Face four, Edge two)	233.0	1.4	268.0	198.1	236.5	3.0	Pass

[a]Although ANSI N42.17A does not cover protocols selected for this test, the criterion for most of the environmental ANSI tests is ± 15% of a reference value. This criterion is used as the evaluation tool for this table.

[b]These data show the range in data for the various environmental conditions.

[c]No data available.

TABLE 17. RESULTS OF ENVIRONMENTAL TESTING COMPARED TO REFERENCE DATA FOR THE AN/PDR-27 AND AN/PDR-43

Item	AN/PDR-27 AN/PDR-43 Criteria	Result	Remarks
Operating Temperature	-40 °C - +60 °C	NA	Pass test temperature range -31 °C - +50 °C
Operating Altitude	Any altitude up to 50,000 feet	NA	Pass altitude test only up to 40,000 feet

NOTE: The Environmental Test Protocol (Appendix B) was developed prior to locating the reference data for the AN/PDR-27 or AN/PDR-43.

Altitude Testing

Low Pressure (Storage)

The pistol grip ADM-300 was subjected to an altitude of 40,000 feet for 1 hour and returned to nominal altitude (512 feet) to simulate the instrument being air transported to a location. The data collected after the storage period elapsed were compared to the data collected before the period began. The test data pass the general 15% ANSI N42.17A requirement. ANSI N42.17A does not have a specific protocol for low pressure storage.

Low Pressure (Operational)

The ADM-300 was subjected to operational conditions at altitudes of 512; 1,000; 5,000; 10,000; 15,000; 20,000; 30,000; and 40,000 feet to determine if there was any altitude dependence of the unit. Four readings were taken at nominal altitude (512 feet) before and after the test and at each altitude. Although ANSI N42.17A, section 8.6, does deal with an instrument's response at various pressures, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. The student's t-test applied to the data collected before and after the test does not indicate any difference in their means. A statistically significant difference in the data was noted, but it is less than the general ± 15% requirement of ANSI N42.17A.

Low Pressure (Rapid Decompression)

The ADM-300 was subjected to an altitude of 40,000 feet and was allowed to undergo a rapid decompression to 512 feet within 35 seconds. Since ANSI N42.17A does not have a protocol for rapid decompression, a protocol from MIL-STD-810D was used for this test. Data collected before the test were compared to the data collected immediately after decompression. The test data pass the general 15% ANSI N42.17A requirement.

Temperature Testing

High Temperature (Operational - Static)

The ADM-300 was subjected to a steady high temperature (49.9 °C) for 2 hours and 15 minutes to simulate working in a desert. Since ANSI N42.17A, section 8.1.1, does not deal with an instrument's response at a constant temperature, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. Although the test protocol required a 14% relative humidity level, the environmental test chamber could not hold the humidity at this level. The humidity level stabilized at 44% and the test was conducted. Because the environmental chamber had reached 34.4 °C when the first data point was taken, this data point was rejected from the data set. The student's t-test applied to the data collected before and after the test does not indicate any difference in their means. The test data pass the general ±15% ANSI N42.17A requirement.

High Temperature (Operational - Diurnal)

This test was not accomplished due to a failure of the environmental chamber to maintain the humidity levels required by the testing protocol.

High Temperature (Storage)

The ADM-300 was subjected to a temperature of 76.6 °C for a period of 4 hours to simulate storing the instrument in an enclosure in heat and direct sunlight of similar intensity as found in the desert. Since ANSI N42.17A, section 8.1.1, does not deal with an instrument's response in storage at a constant temperature, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. Data collected before the test were compared to the data collected immediately after the test cycle was completed. The average reading after the test is within the general 15% requirement of ANSI N42.17A. The average reading after the test shows an increase of 6.5% over the average reference reading.

Low Temperature (Storage)

The ADM-300 was subjected to a temperature of -31 °C (-24 °F) for a period of 4 hours to simulate storing the instrument in an enclosure in the cold and wind similar to that found in arctic regions. Since ANSI N42.17A, section 8.1.1, does not deal with an instrument's response at a constant temperature, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. The data collected after the storage period elapsed were compared to the data collected before the period began. The test data pass the general 15% requirement of ANSI N42.17A.

Low Temperature (Operational - Diurnal)

The ADM-300 was subjected to operational conditions at low temperatures to simulate a day's work out in a cold climate. Since ANSI N42.17A, section 8.1.1, does not deal with an instrument's response under diurnal conditions, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. MIL-STD-810D provided a diurnal temperature cycle 12 °C, 0 °C, -11 °C, -20 °C, -31 °C, -20 °C, and -11 °C for the 7-hour test. The data sets collected before and after the test were combined and used as the reference for comparison with the average result at each temperature setting. The test data pass the general 15% ANSI N42.17A requirement. The lowest reading was recorded at -31 °C and was a decrease of only 2.3% from the reference value.

Although fresh batteries had been placed into the ADM-300 prior to the test cycle, a low battery indicator was first noticed at 1.25 hours into the test and the crystal screen turned dark (but still readable) at 2.5 hours into the test. Both conditions continued throughout the test cycle until the instrument was allowed to warm to ambient temperatures. This could have had an effect on the test results, especially the data collected after the test cycle had been completed. Since a battery failure could have been a limitation rather than the instrument, this test should be reaccomplished by removing the batteries from the ADM-300 unit and supplying the instrument with a power source external to the environmental chamber.

Low Temperature (Operational - Static)

The ADM-300 was subjected to a steady temperature of -31 °C (-24 °F) for 2 hours and 15 minutes to simulate working in an arctic climate with little temperature change. Since ANSI N42.17A, section 8.1.1, does not deal with an instrument's response under constant temperature conditions, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. The data sets collected before and after the test were combined and used as the reference for comparison with the average result of the test data. A statistically significant difference in the data was noted, but it is less than the general ± 15% requirement of ANSI N42.17A.

Although fresh batteries had been placed into the ADM-300 prior to the test cycle, a low battery indicator was first noticed at 45 minutes into the test, and the crystal screen turned dark and very hard to read at 2 hours into the test. Both conditions continued throughout the test cycle until the instrument was allowed to warm to ambient temperatures. A flashing "E" was seen on the display after a 20-minute warm-up period, but was not seen during the testing. This low battery condition could have had an effect on the test results. Since a battery failure could have been a limitation rather than the instrument, this test should be reaccomplished by removing the batteries from the ADM-300 unit and supplying the instrument with a power source external to the environmental chamber.

Temperature Shock (High Temperature)

The ADM-300 was moved from an ambient temperature level to a temperature of +50 °C (+122 °F) to simulate taking the instrument from a normal environment into an environment as can be found in the desert. The instrument was allowed to remain in this hot environment for at least 1 hour before it was removed and placed into the ambient environment.

The data collected after the test period elapsed were compared to the data collected before the period began. They are within the general 15% requirement of ANSI N42.17A. The average reading after the test shows an increase of 4.3% over the average reference reading.

The data collected at the shock temperature were compared to the data collected before the test began. They are within the general 15% requirement of ANSI N42.17A. The average reading after the test shows an increase of 4.7% over the average reference reading.

The data collected for this test could be a product of its environment. This test was initiated within 25 minutes of the cold temperature shock test, and the internal components of the instrument may not have been warmed to ambient temperatures before the test was initiated. Another factor that could affect the test results is in the way the readings at the high temperature were taken. These readings were spread out over the time the instrument was in the hot environment instead of being taken immediately when the instrument was placed into the chamber. This test should be repeated to remove these potential problems.

Temperature Shock (Low Temperature)

The ADM-300 was moved from an ambient temperature level to a temperature of -31 °C (-24 °F) to simulate taking the instrument from a normal environment to be used in an environment as can be found in the arctic (e.g., taking the instrument out of a warm vehicle to the cold environment). It was allowed to remain in this environment for at least 1 hour before it was removed and placed into the ambient environment.

The data collected after the test period elapsed were compared to the data collected before the test began. They are within the general 15% requirement of ANSI N42.17A. The average reading after the test shows a decrease of 4.3% over the average reference reading.

The data collected at the shock temperature were compared to the data collected before the test began. They are within the general 15% requirement of ANSI N42.17A. The average reading after the test shows a decrease of 3.7% over the average reference reading.

The readings collected at the test temperature were also spread out over the time the instrument was in the cold environment (i.e., over the 1-hour time period) instead of being taken immediately when the instrument was placed into the chamber. This test should be repeated to remove this potential problem.

Humidity Testing

Humidity Test (Operational - Diurnal Induced)

The requirements for this test were to simulate a hot, humid environment such as one would find along the coastal areas of the United States. Since ANSI N42.17A, section 8.3.1, does not deal with an instrument's response under diurnal humidity conditions, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. This called for temperatures and humidity levels to fluctuate throughout the test period. However, the environmental chamber experienced a problem in controlling its humidity levels below 80%. Because of this, one test cycle for the high temperature diurnal test that called for relative humidity levels down to 14% and temperatures as high as 43.3 °C could not be accomplished. Instead, the high temperature diurnal test was accomplished with an average humidity level of 97% and temperatures as high as 43.3 °C. Since the humidity levels were so high, this data set was considered to be another data set for the Humidity Test (Operational - Diurnal Induced).

No data were collected at the end of the first data set; therefore, a before vs. after comparison of the data could not be made for this data set. The data sets collected before and after the second test were combined and used as the reference for comparison with the average result at each temperature setting. The test data pass the general 15% ANSI N42.17A requirement. The lowest reading was recorded at -31 °C and was only a decrease of 2.3% from the reference value.

Humidity Test (Operational - Static)

The ADM-300 was subjected to a steady temperature of 30 °C (86 °F) and relative humidity (90% or greater) for 2 hours and 15 minutes to simulate working along the coastal plains of the United States, as specified in MIL-STD-810D. The data sets collected before and after the test were combined and used as the reference for comparison with the average result of the test data. The test data pass the ± 15% ANSI N42.17A requirement.

Vibration Testing

Sinusodial Vibration

The ADM-300 was subjected to a logarithmic sine wave along the x-, y-, and z-axis of the instrument over the frequency range of 5-500 Hertz. Although ANSI N42.17A, section 8.5, does deal with an instrument's response while being vibrated, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. The data collected after the test were compared to the data collected before the test began. The test data for all axes pass the general 15% ANSI N42.17A requirement.

ANSI N42.17A states that the physical condition of the instruments shall not be affected by this vibration. During the vibration testing, a couple of capacitors broke loose inside the instrument case and caused the instrument to fail. These loose connections were resoldered. The technician performing this task noted that many of the electronic components were not closely secured to the unit. In agreement with the manufacturer, RTV adhesive was placed around all the electronic connections to provide cushioning of these components to prevent additional instrument failures.

Random Vibration

The ADM-300 was subjected to a random 2 G force applied along the x-, y- and z-axis over the range of 11-2,000 Hertz. Although ANSI N42.17A, section 8.5, does deal with an instrument's response while being vibrated, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. The data collected after test completion were compared to the data collected before the test began. The test data are within the general 15% ANSI N42.17A requirement for all axes.

Shock Testing

Transit Drop

This test requires the instrument to be dropped from a height of 40 inches onto the floor surface. This test was not accomplished.

Bench Handling

The ADM-300 was subjected to a drop onto a wood surface to simulate rough handling during shop tests. Although ANSI N42.17A, section 8.4, does deal with an instrument's response during mechanical shock, the ADM-300 was subjected to the test protocol of MIL-STD-810D rather than ANSI N42.17A. One edge of each side of the unit was maintained in contact with the bench top and the other edge was raised to a maximum height of four inches before it was released. Two tests per side for a total of eight tests were run. The data collected after test completion were compared to the data collected before the test began. All test data pass the general 15% ANSI N42.17A requirement. In all instances, there was no damage to the physical condition of the instrument.

CONCLUSIONS

The NRC's ADM-300 RADIAC instrument surpasses most of the reference data for the AN/PDR-27 listed in T.O. 11H4-7-3-201 and the AN/PDR-43 listed in T.O. 11H4-7-3-181. The photon energy response was outside the ± 20% requirement listed in the reference data at effective energies of 120 keV and 140 keV. Two environmental conditions were not fully tested in accordance with the reference data for these RADIAC instruments:

(1) The altitude test did not go to 50,000 feet. The instrument did pass the ANSI N42.17A requirements at all altitudes up to 40,000 feet.

(2) The temperature test was not as extreme as specified in the reference data. The instrument did pass the 15% general ANSI N42.17A requirements for the temperature range between -31 °C to +50 °C.

Testing the ADM-300 survey meter against ANSI N42.17A indicates it meets the majority of the requirements of that standard. The user should be made aware of the minor shortfalls of the ADM-300 instrument such as not changing to units of dose when the instrument is being used in the "dose mode," not having the calibration points clearly marked on the instrument case, and only having a low battery indicator instead of a battery status indication. Due to an alarm activation delay, the user could be exposed to greater than 10 mrem of radiation in photon fields greater than 1.3 R/hr.

In general, the deviation from the true delivered exposure is less than 5% between 1 μR/hr to 2,000 R/hr. However, when approaching its maximum range, one instrument overresponded by approximately 27% (Table 9 and Fig. 4). Relying on the one point calibration system, as stated by the manufacturer's literature, provided an extremely low response to this high radiation field. In accordance with the ADM-300 Operator's Manual, the user should use radiation sources capable of producing a field of 100 mR/hr to calibrate the low range tube and a field of 400 R/hr to calibrate the high range tube. Once recalibrated with these fields, the instrument provided the above stated results.

The ADM-300 appears to have a flat energy response from 252 keV through 1,250 keV. However, it overresponded by 138% at an effective energy of 120 keV and underresponded by 73% at an effective energy of 140 keV (Table 12 and Fig. 5). Using photon check sources, the ADM-300 could detect the 60 keV peak from Am-241 but only with the beta window open. The instrument could easily detect the low energy emissions from a Cs-137 check source with the beta window open (Table 13), and it had no problem detecting the presence of beta particles from check sources with energies greater than Pm-147 (Table 14 and Fig. 6).

The angular dependence of the ADM-300 is dependent upon the electronics package through which the radiation must travel to get to the detector. Because the detector is mounted in the unit, neither type of instrument configurations passed the requirements of ANSI N42.17A for all axes of rotation. The ADM-300 unit with the beta window on the bottom has less angular dependence than the unit with the beta window along the side (Table 15 and Figures 7-12).

The instrument did not fail any of the environmental tests when the general requirement of ± 15% as used by ANSI N42.17A was applied. The maximum coefficient of variation for the environmental tests was only 3.1%, thus the range of the statistical test results was well within the requirements of the ANSI N42.17A. Technically, the ADM-300 failed the vibration test because two capacitors were broken loose during the testing. Once repaired and all other connection cushioned with RTV adhesive, the instrument continued to perform well. The only other problem noted was that the low battery indicator was illuminated under "cold" test conditions and the display became dark or hard to read. Once the instrument was allowed to warm up, both these conditions returned to normal. This could be a direct result of battery limitations rather than an instrument limitation.

Even though the instrument could have an energy dependence, it clearly surpasses the performance of the AN/PDR-27 and the AN/PDR-43 and should be considered as a replacement item for these instruments.

RECOMMENDATIONS

If one is considering procurement of the ADM-300, the style of the unit with the beta window along the end of the unit should be considered over the style of unit with the beta window along the side of the unit. The manufacturer should be required to correct some of the shortfalls of the instrument (e.g., making the "dose mode" read out in the proper units, marking the calibration points on the instrument, cushioning of the electronic components, etc.). The ADM-300 without a "slit" in the detector tube shielding should be tested for photon energy dependence. Although the ADM-300 passed the general 15% requirement of ANSI N42.17A for environmental testing, additional testing under "cold" conditions should be repeated with an external power source to determine the instrument's environmental limitations separate from the possible battery limitations. If external probes for the ADM-300 are considered, Armstrong Laboratory should be tasked to perform a similar evaluation of the instrument's response with the external probe.

REFERENCES

1. American National Standard Institute (ANSI), American National Standard Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Environmental Conditions. Institute of Electrical and Electronics Engineers, Inc., ANSI N42.17A-1989.

2. MIL-STD-810D, Environmental Test Methods and Engineering Guidelines (19 Jul 83).

3. Technical Order 11H4-7-3-201, RADIAC Set AN/PDR-27T - Operation, Maintenance & Overhaul with Parts Breakdown (1 Oct 82).

4. Technical Order 11H4-7-3-181, RADIAC Set AN/PDR-43E (20 Jan 74).

5. Operator's Manual, ADM-300 Multifunction Survey Meter, Nuclear Research Corporation, (21 Nov 90).

6. International Commission on Radiological Protection (ICRP) Publication 60, 1990 Recommendations of the International Commission on Radiological Protection, Annual of the ICRP, Vol 21, Numbers 1-3, New York: Pergamon Press Inc., (1991).

APPENDIX A

RADIAC RADIATION TESTING PROTOCOL

RADIAC RADIATION TESTING PROTOCOL

INTRODUCTION

Radiation testing of the ADM-300 is to determine whether the unit is a suitable replacement for the AN/PDR-27 and AN/PDR-43. Because there is not a MIL-STD that outlines a protocol for testing RADIACs, most of this test protocol follows the American National Standards Institute (ANSI) Standard N42.17A, Performance Specifications for Health Physics Instrumentation - Portable Instrumentation for Use in Normal Environmental Conditions. Some of the tests are required to determine the ADM-300's performance against the reference data for the AN/PDR-27 and AN/PDR-43 instruments as found in Technical Order (T.O.) 11H4-7-3-201 and T.O. 11H4-7-3-181 respectively. These tests are marked with an asterisk.

TESTING PROTOCOL

Standard Test Conditions

Test conditions for all radiation performance testing shall fall within the limits set by the ANSI N42.17A, Table 1.

Battery Power Test*

ANSI N42.17A procedure 4.11.2 shall be used. The instruments shall operate for a minimum of 40 hours with the reading varying no more than 10% over that interval. The test will be terminated after 100 hours or until the unit fails, whichever may come first.

Alarm Test

ANSI N42.17A procedures 5.2.2.1 and 5.2.2.2 shall be used. Alarm set points in each range shall be tested. The alarm set points for each range shall be 50% of the full scale reading. The delay in the alarm activation should be such that the exposure that results from the delay does not exceed 10 milliroentgens (mR).

Stability Test

ANSI N42.17A procedure 5.3.2 shall be used. Drift should not exceed 6% from the mean of a set of reference readings over a period of 3 hours under constant temperature and pressure conditions.

Geotropism Test

ANSI N42.17A procedure 5.4.2 shall be used. Results of this test shall be documented but no pass/fail criteria will be applied.

Response Time Test

ANSI N42.17A procedure 5.5.2 shall be used. The maximum time for the instrument to reach 90% of the conventionally true value on any range shall not exceed 10 seconds.

Coefficient of Variation Test

ANSI N42.17A procedure 5.6.2 shall be used. The coefficient of variation should not exceed 10%.

Accuracy Test

ANSI N42.17A procedure 6.1.2.1 shall be used. Three points on each scale (20, 50, and 80% of full scale) shall be tested. Cs-137 shall be used for all ranges with the exception of the 10,000 R/hr range. Co-60 shall be used for this range. Accuracy shall be evaluated in both rate meter and scaler mode. In the scaler mode a 1-minute count time shall be used. Accuracy in both modes shall be within +/-20% of conventionally true values.

Photon Energy Dependence Test*

ANSI N42.17A procedure 6.3.2 shall be used. Performance at 80 keV (National Institutes of Standards and Technology Beam Code H100) shall be within 20% of the Conventionally True Value. Performance at 40 keV (National Institutes of Standards and Technology Beam Code H50) shall be documented, but no pass/fail criteria will be applied at this energy.

Beta Energy Dependence Test*

ANSI N42.17A procedure 6.4.2 shall be used. International Standards Organization (ISO) 6980, Series 1 sources shall be used. Only detection of the radiation will be documented. Performance below maximum beta energy of 130 keV shall not be performed.

Angular Dependence Test

ANSI N42.17A procedure 6.7.2 shall be used. No pass/fail criteria shall be applied to this test.

Neutron Sensitivity Test

ANSI N42.17A procedure 7.6.2 using a PuBe source producing a 15 mrem/hr fast (>0.1 MeV) and Cf-252 source producing an 8 mrem/hr (fission spectrum) dose equivalent rate neutron field shall be used. Response shall be documented but no pass/fail criteria will be applied. The photon exposure rate from the Cf-252 source shall be subtracted from the response of the instrument under test.

APPENDIX B

RADIAC ENVIRONMENTAL TESTING PROTOCOL

RADIAC ENVIRONMENTAL TESTING PROTOCOL

STANDARD INSTRUMENT MEASUREMENTS

The instrument shall be installed into the test chamber in accordance with MIL-STD 810D (Jul 83), Section 4.5.2. The test item shall be operated according to the ADM-300 Operator's Manual and directions of the Instrumentation and Calibration Facility (ICF) personnel. The instrument shall be turned on and allowed to stabilize before any readings are taken. All data collected during the testing cycle shall be recorded on forms provided by the ICF. Anytime the ADM-300 fails to perform or an error code is illuminated on the ADM-300, the test shall be terminated. At the end of each test cycle, the instrument shall be inspected for any damage.

ALTITUDE TESTING

Low Pressure (Storage)

Environmental Requirements

MIL-STD 810D (Jul 83), Method 500.2, Procedure I shall be used. The test procedure shall include a 40,000-foot altitude exposure for not less than 1 hour. Altitude rate changes should not exceed 2,000 feet per minute. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall be operable without degradation in specified performance and shall withstand air transportation at altitudes up to 40,000 feet above sea level. Four readings shall be taken prior to and after the end of the altitude testing for storage. This test should not last longer than 2 hours.

Low Pressure (Operational)

Environmental Requirements

MIL-STD 810D (Jul 83), Method 500.2, Procedure II shall be used. The test procedure shall include operational test at 1,000 feet; 5,000 feet; 10,000 feet; 15,000 feet; 20,000 feet; 30,000 feet; and 40,000 feet. Altitude changes should not exceed 2,000 feet per minute. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall be operable without degradation in specified performance and shall be operational at altitudes up to 40,000 feet above sea level. Four readings shall be taken prior to and after the end of the altitude testing for operations and at each altitude increment listed above. The test should last approximately 1 hour in duration.

Low Pressure (Rapid Decompression)

Environmental Requirements

MIL-STD 810D (Jul 83), Method 500.2, Procedure III shall be used. The test procedure shall include an altitude equivalent to 40,000 feet. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall be operable without degradation in specified performance. Four readings shall be taken prior to and after the end of the altitude testing for rapid decompression. The test should last approximately 30 minutes in duration.

TEMPERATURE TESTING

High Temperature (Operational)

Environmental Requirements

MIL-STD 810D (Jul 83), Method 501.2 Procedure II shall be used. This test shall include operational testing during a conceived diurnal cycle temperatures for two conditions: (1) Induced Conditions (Hot), Table 501.2-I; and (2) Ambient Air Conditions (Basic Hot), Table 501.2-II. In addition, static temperature test shall be conducted at an ambient temperature of +50 °C and a relative humidity of 14% for no less than a 2-hour period. The rate of temperature change shall not exceed 10 °C per minute. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

Diurnal Cycle

The equipment shall be operable without degradation during conceived diurnal cycles. The conceived diurnal cycle used for this test will use the temperatures and relative humidities listed in Table 501.2-I for Induced Conditions (Hot) and Table 501.2-II for Ambient Air Conditions (Basic Hot) using the times of 0600, 0900, 1200, 1500, 1800, 2100, and 2400. The temperature will be raised to the specified temperature and maintained for 1 hour. Instrument readings will be taken at 15-minute intervals. The diurnal tests should not exceed 8 hours a day and will be repeated for three cycles for the Ambient Air Condition (Basic Hot), but only one cycle will be run for the Induced Conditions (Hot).

Static Temperature

The equipment shall be operable without degradation in specified performance at ambient temperatures of +50 °C and relative humidity of 14% for a period long enough to collect at least 10 readings taken at 15-minute intervals. The static temperature test should not exceed 3 hours.

Reliability Tests

The thermal stress shall be applied in an operating range of 30-71 °C (86-160 °F) and a hot soak temperature of +50 °C (122 °F).

High Temperature (Storage)

Environmental Requirements

MIL-STD 810D (Jul 83), Method 501.2 Procedure I shall be used. The instrument will be exposed to an ambient air temperature of +75 °C for 4 hours. The rate of temperature change shall not exceed 10 °C per minute. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall withstand exposure to ambient air temperature up to +75 °C and be maintained for at least 4 hours. Four readings will be taken prior to the storage test and at the end of the storage test. The tests should not exceed 5 hours in 1 day.

Reliability Tests

The thermal stress shall be applied as a hot soak of +75 °C.

Low Temperature (Storage)

Environmental Requirements

MIL-STD 810D (Jul 83), Method 502.2, Procedure I shall be used. The specified temperature shall be maintained for a storage period of 4 hours. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall withstand exposure to ambient air temperature down to –65 °C for a period of 4 hours without degradation in specified performance. New batteries shall be placed in the instrument prior to beginning this test. Four readings shall be recorded prior to and at the end of the testing cycle.

Reliability Tests

The thermal stress shall be applied in a cold soak temperature of -65 °C (-79 °F).

Low Temperature (Operational)

Environmental Requirements

MIL-STD 810D (Jul 83), Method 502.2, Procedure II shall be used. Two tests shall be used for this testing: (1) Operation during a conceived diurnal cycle without cold storage prior to the test (i.e., ambient storage), and (2) Operation during a static cold temperature of -31 °C for 4 hours. The rate of temperature change shall not exceed 10 °C per minute. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

Diurnal Cycle

The equipment shall be operable without degradation during conceived diurnal cycles. The conceived diurnal cycle used for this test will use the following temperatures: 12 °C, 0 °C, -11 °C, -20 °C, -31 °C, -20 °C, and 11 °C. The temperature will be lowered to the specified temperature and maintained for 1 hour. Instrument readings will be taken at 15-minute intervals. (NOTE: LCD crystals may freeze at these temperatures. If this occurs, record the temperature and terminate this test cycle.) The diurnal tests should not exceed 8 hours in 1 day. This test will be conducted with the instrument starting from a normal (ambient) storage position.

Static Temperature

The equipment shall be operable without degradation in specified performance at ambient temperatures of -31 °C for a period long enough to collect at least 10 readings taken at 15-minute intervals. The static temperature test should not exceed 3 hours. (NOTE: LCD crystals may freeze at these temperatures. If this occurs, record the temperature and terminate this cycle of test.)

Reliability Tests

The thermal stress shall be applied in an operating range of 12 to -31 °C (54 to -24 °F).

Temperature Shock

Environmental Requirements

MIL-STD 810D (Jul 83), Method 503.2, Procedure I shall be used. The shock hot-temperature test shall be from ambient temperature to +50 °C (122 °F) and returned to ambient temperature. The shock cold-temperature test shall be from ambient temperature to -31 °C and returned to ambient temperature. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall be operable without degradation in specified performance. The equipment shall be unprotected and readings shall be taken every 15 minutes after the instrument has been introduced into the environment for 1 hour (i.e., there will be four readings for each temperature extreme). The equipment shall be introduced into the shock environment in less than 5 minutes (i.e., the time to move the instrument from ambient to the hot environment shall be less than 5 minutes and the time to move the instrument from the hot environment to ambient shall be less than 5 minutes. The same applies for the cold-temperature test).

Reliability Tests

The thermal stress shall be applied in a hot soak temperature of +50 °C (122 °F) and a cold soak temperature of -31 °C (-24 °F).

HUMIDITY TEST

Hot Humid Conditions

Environmental Requirements

MIL-STD 810D (Jul 83), Method 507.2, Procedure I shall be used. This test shall include operational testing during a conceived diurnal cycle temperatures conditions found in Table 507.2-I under Natural High Humidity Cyclic (Cycle 3). In addition, static temperature test shall be conducted at an ambient temperature of +30 °C and a relative humidity of 95% or better. The rate of temperature change shall not exceed 10 °C per minute. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

Diurnal Cycle

The equipment shall be operable without degradation in specific performance during conceived diurnal cycles. The conceived diurnal cycle used for this test will use the temperatures and relative humidities listed in Table 507.2-I for Cycle 3 using the times of 0600, 0900, 1200, 1800, 2000, and 2300. Since the temperature and humidity for 1500 is similar to 1200, the temperature will be raised to 38 °C (100 °F) and the relative humidity at 69%. The temperature will be raised to the specified temperature and maintained for 1 hour. Instrument readings will be taken at 15-minute intervals. The diurnal tests should not exceed 8 hours in 1 day.

Static Temperature

The equipment shall be operable without degradation in specified performance at ambient temperatures of +30 °C and relative humidity of 95% or better for a period long enough to collect at least 10 readings taken at 15-minute intervals. The static temperature test should not exceed 3 hours.

Reliability Tests

Moisture levels sufficient to cause visible condensation and frosting shall be used. Humidity need not be held constant during the test cycle, and high levels may be accomplished by moisture injection at appropriate times in the test cycle.

MECHANICAL SHOCK

Vibration Test

Environmental Requirements

MIL-STD 810D (Jul 83), Method 514.3, Procedure I shall be used. This test shall be performed after all other environmental testing has been accomplished, except the shock test. The instrument will not be in an instrument carrying case but will simulate transport to the field as secured cargo. The test will last a minimum of 1 hour per axis of vibration. The vibration shall be sinusodial. In addition, a random vibration test shall be performed. If an instrument carrying case is available, these tests will be repeated with the instrument in the case. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

Sinusodial Test

The equipment shall be operable without degradation in specific performance during sinusodial testing. The swept sine wave vibration shall be applied over a frequency range of 5 to 500 Hertz (Hz) and follow the vibration levels found in Figure 514.3-35 with the following exceptions: (1) The displacement from 5-14 Hz shall have a double amplitude of 0.2 inch, and (2) a 2 G force shall be applied from 14-500 Hz. These test logarithmic sweeps shall be applied five consecutive times during the testing cycle. Four readings shall be recorded prior to and upon termination of the test for each axis of testing. It is desirable to have readings taken during the testing cycle, but this is not a test requirement.

Random Test

The equipment shall be operable without degradation in specific performance during the random vibration test. Frequencies of vibration shall vary between 11 Hz to 2,000 Hz. The test will last for 30 minutes per axis of vibration. A minimum of 4 readings shall be recorded prior to and upon termination of the test cycle. It is desirable to have readings taken during the testing cycle, but this is not a test requirement.

Reliability Tests

The logarithmic swept sine wave shall be over a frequency range of 5 to 500 Hz as follows: 0.2 inch double amplitude for 5-14 Hz and 2 G from 14-500 Hz. The vibration shall be applied for 15 minutes per hour of operation.

Transit Drop

Environmental Requirement

MIL-STD 810D (Jul 83), Method 516.3, Procedure IV shall be used. If a carrying case is available, the instrument shall be dropped on each face from a height of 40 inches onto the floor surface. If no instrument case is available, the instrument shall be *dropped onto its bottom surface from a height of 40 inches onto a floor surface only* once. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall be operable without degradation in specific performance after being dropped on each face of the instrument. The instrument and case shall be dropped from a height of 40 inches. If the instrument or instrument case topples after the drop, it should not be restrained, provided it does not leave the required surface. Four readings shall be recorded before and after each drop test are complete.

Bench Handling

Environmental Requirement

MIL-STD 810D (Jul 83), Method 516.3, Procedure VI shall be used. An instrument case shall not be used for this test. Four drop tests on a wooden bench top surface shall be conducted for each test condition. If the instrument has a scalar mode, 1-minute counts shall be used.

Environmental Service Conditions

The equipment shall be operable without degradation in specific performance after being dropped on each face of the instrument. The test item shall not be operating during the drop test. With one edge of the instrument remaining on the bench surface, the opposite edge of the instrument shall be raised to a height of 4 inches and dropped back onto the horizontal surface of a wooden bench top. This will be repeated 4 times for each of the two edges that define the length of the instrument surface. Four readings shall be recorded before and after the drop test on each surface. A total of 24 readings shall be recorded per instrument.

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